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Final Report On

The Launching and Landing of Carrier Aircraft

Contract ONR 583 (01)
December 1952

Part IV
Of Four Parts

Part I General Report
Part II Limitations of Cable-Drive Catapults
Part III A Multi-Jet Driven Catapult (Hydrapult)
➡ Part IV Barricades

By

A University of Kansas Research Group
University of Kansas
Lawrence, Kansas

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BARRICADES

Part IV of the Final Report on

THE LAUNCHING AND LANDING OF CARRIER AIRCRAFT

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of 25 copies
made originally

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PREFACE

In August 1951 a University of Kansas Research group was assigned to study the general problem of the launching and landing of carrier aircraft. The work was done under contract ONR 583 (01). The purpose of the study was to obtain from a well-trained diversified group not too imbued with past and present Navy thinking and procedure, an independent evaluation of the problem and possible methods of solution, emphasis being placed upon development to meet future needs rather than just to solve immediate problems.

It was left to the group to choose those aspects of the problem on which to concentrate. As a result, certain aspects of the problem have been studied intensively while others have been considered only superficially. In analyzing the problem and dividing it into its several aspects, the group asked two questions:- (1) Is this aspect of the problem of decided importance? (2) Can the group make a worthwhile contribution by studying intensively this aspect of the problem? Emphasis was placed upon those aspects for which the answer to each question was affirmative.

The group submits its final report in four parts. The title and general content of each part is as follows:

Part I. General Report.

This section presents in a comprehensive yet understandable manner the problem as the group sees it, and makes clear what the group believes can and/or should be done. This section is relatively free of details but comprehensive as regards general conclusions.

Part II. Limitations of Cable-Drive Catapults.

This section presents a detailed study of the limitations of cable-drive catapults and the relative effects of different modifications of cable drives. It is rather analytical.

Part III. A Multi-Jet Driven Catapult (Hydrapult).

This section presents the results of a study of a multi-jet catapult which the group refers to as a "hydrapult." Although emphasis is placed upon the general features and operation of the proposed hydrapult, numerous details are included.

Part IV. Barricades.

This section presents the results of a model study of barricades. It contains many tabular data giving force distributions among the various elements of typical barricades. Numerous photographs are included.

The University of Kansas Research Group assigned to study this problem and submit this report was composed of the following staff members:

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1 Resigned from group January 15, 1952.
2 Resigned from group August 15, 1952.
3 Resigned from group March 12, 1952.

BARRICADES

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INTRODUCTION

Although the barricade constitutes but a small part of the over-all launching and landing problem aboard carriers, and although the barricade in current use appears rather satisfactory for planes now employed on aircraft carriers, the group has nevertheless felt that the problem of barricade design warranted further quantitative study. This feeling rests upon the following facts:

1. Barricade failure may be very expensive both as regards loss of life and damage to planes. The deck crew and parked planes are endangered equally with the pilot and the particular plane he is attempting to land.

2. In each of two barricade demonstrations at the Philadelphia Navy Yard witnessed by the group in August 1951, the barricade failed. Although important modifications have been made since then, the group feels that any possible improvement in the basic design should not be overlooked.

3. It appears that little is known about the force distributions in the several elements of barricades in use or considered. Even approximate data on the force distributions might provide a basis for future modifications of present designs, or provide a basis of judging the probable merits of other designs which might be suggested.

4. Barricades will soon be needed to stop planes with wings swept back from 45° to 60°. This will certainly introduce larger forces. It would be well to consider the basic features of simple possible designs.

The study group has therefore considered the problem of barricades in general, attempted to state those characteristics which determine the merit of a particular barricade, made quantitative measurements of some of the static characteristics of typical barricades, and arrived at certain conclusions.

GENERAL CONSIDERATIONS

Nearly all planes are stopped by an arresting cable picked up by the tail hook. Most of those not stopped by an arresting cable are stopped by a barrier. The problem of stopping those few that pass both the arresting cables and the barriers involves but a small fraction of the planes landing. The problem is nevertheless important because of the loss of life and damage to planes which would occur if these planes were not stopped. The best practical solution of the problem may well be different for large and for small carriers.

Neglecting for the moment all other operations which prescribe and limit space assignment on the landing deck, it seems clear that the best solution would be to dispense with the barricade and let those few planes which are not stopped by an arresting cable or a barrier go into the sea. This solution would probably not increase materially, if at all, the chance of serious injury to the pilot. It might result in more extensive damage to the plane. A majority of planes stopped by the barricade are already damaged, however, and many will be damaged still more by engaging the barricade. If reliance is placed in a barricade, failure of the barricade is likely to result not only in far more serious injury to the pilot and greater damage to the plane than would result from going into the sea, but it also endangers deck personnel and parked planes. Even a rare failure would probably cause injury to personnel and damage to planes above the average which would result from allowing all planes now caught by a barricade to go into the sea.

Even apart from the possibility of using a "going-into-the-sea barricade," there is much to be said for the existence of separate and simultaneously usable launching, landing and parking facilities. The desirability of such facilities is greater on a large carrier, having a correspondingly larger complement of planes, than on a small carrier. It is the opinion of this group that the advantages of separate facilities will ultimately lead to their installation on large carriers, and that in such instance the normal barricade should be eliminated and the plane allowed to go into the sea.

The small or medium carrier presents a different problem. Separate launching, landing and parking facilities can probably never be provided without an untenable reduction in the plane complement. Some deck barricade will probably always be necessary. Since planes used on even small and medium carriers will undoubtedly become faster and probably become heavier, the future increases in landing speed and weight, coupled with the almost certain use of sweptback wings, will make the barricade

problem considerably more difficult than it is at present. The group has therefore deemed it important to study the problem of barricade design in some detail.

The primary question is, what are the characteristics of a barricade which determine its merit? The principal desirable characteristics of a barricade are the following:-

1. The barricade should stop the plane regardless of how badly the plane may be damaged. It is particularly important that damage which might render the normal arresting cables inoperative, or damage which would cause the normal barriers to fail, should in no way lessen the effectiveness of the barricade. Any plane that the pilot is able to return to the carrier is certain to have at least the fuselage and the wing structure more or less intact. It would be well to assume no more than this minimum, and to have the barricade operate upon one or the other of these structures. It is difficult to see how any engagement with the fuselage can be accomplished, except perhaps with a loop around the nose, in which case the actual engagement would even then be primarily on the wing's leading edge next the fuselage. Thus it appears reasonably certain that any barricade should engage the wing structure.

2. The forces with which the barricade retards the plane should be distributed over the plane in such a manner as to avoid placing undue local stresses on the plane.

3. The tensions in various similar elements of the barricade should be as nearly equal as possible, and the equality among elements should be maintained for all values of runout. Insofar as possible also, these forces should pull directly opposite the direction of the plane's motion. These two conditions minimize the stress to which the most stressed element is subjected.

4. The forces which act on the plane, as for example on the leading edge of the wing, should be as nearly perpendicular as possible to the surface on which they act. This condition minimizes the tendency of a barricade element to slide along the wing. It seems probable that sliding of an element along the leading edge of a wing may contribute materially to tearing of both the element and the wing. This desirable requirement is not always consistent with the preceding requirement (3); a compromise will usually be necessary.

5. For an off-center landing, any component of force exerted on the plane perpendicular to the center line of the landing deck should be directed toward this center line. The only exception to this would be for an off-center landing with the plane velocity having an appreciable component toward the center line. For a plane velocity parallel to the center line no centrally directed component of force is particularly necessary, though a small one would certainly not be undesirable. In a landing for which the plane velocity has an appreciable component directed away from the center line, a relatively large component of force toward the center line is highly desirable.

6. For a center landing in which both the fuselage and the plane's velocity are parallel to the center line, no torque is necessary though a small one would not be undesirable. For a center landing in which the fuselage is parallel to the plane's velocity but in which the velocity is not parallel to the center line, the torque should be in such a direction as to orient the fuselage more nearly parallel to the center line.

7. The distribution of the forces exerted on the plane (2), the equality of tensions in various similar elements of the barricade (3), and the directions of these forces (3 and 4), should be as nearly as possible the same for an off-center landing as for a center landing, except insofar as a change may be required to produce a desirable component of force directed perpendicular to the center line (5) or a desirable torque tending to turn the plane (6).

8. The distribution of forces on the plane (2), the equality of tensions in various similar elements of the barricade (3), and the directions of these forces (3 and 4), should be as nearly as possible the same for a landing (either center or off center) in which the axis of the fuselage is skewed with respect to the direction of motion of the plane as for a normal landing, except insofar as a change may be required to produce a more desirable component of force directed perpendicular to the center line (5) or a more desirable torque tending to turn the plane (6).

9. The behavior of the barricade should be as nearly independent as possible of the configuration of the plane, as for example, independent of the wing span and the angle at which the wings are swept back.

10. The barricade should be such that during an engagement there is little chance of the plane flipping over, and little chance of entanglement of the barricade with the landing gear or tail fin in such a manner as to render the barricade inoperative.

11. The barricade should be highly resistant to weather damage. It should be expendable and easily replaceable. It should not impede traffic nor be damaged by traffic.

It would be too optimistic to hope that any possible design could meet all of these requirements. Any practical design must be but a compromise, and perhaps even a none too desirable compromise. Nevertheless, recognition of the various desirable characteristics, coupled with quantitative analyses of the characteristics of proposed designs, should aid materially in choosing the most satisfactory design.

From general consideration of the requirements stated above, one can scarcely escape the conclusion that the best barricade would be one constructed to resemble a continuum of highly flexible elements capable of great stretch without failure. It would be advantageous in the attempt to equalize forces in the elements of the barricade if the elements could be made of some material which, after suffering a given percentage elongation, offered a resisting force that is independent of the elongation. There are materials that show this characteristic to a considerable degree, but to the best of the knowledge of the group none of these is a suitable material from which to fabricate a barricade. In any case one would wish to have the barricade behave in many respects like a flexible rubber diaphragm, the rubber of which is capable of great stretch before failure. Lack of a material which can be stretched sufficiently without failure and at the same time meet other necessary requirements of strength, durability, etc., will probably make it necessary to go to a finite number of elements arranged in such a fashion that the equalization of tension does not depend too drastically upon the ability of the element to stretch. Actual analysis of the force distributions among the elements of any proposed barricade therefore becomes important.

BARRICADES FOR PLANES WITH STRAIGHT WINGS

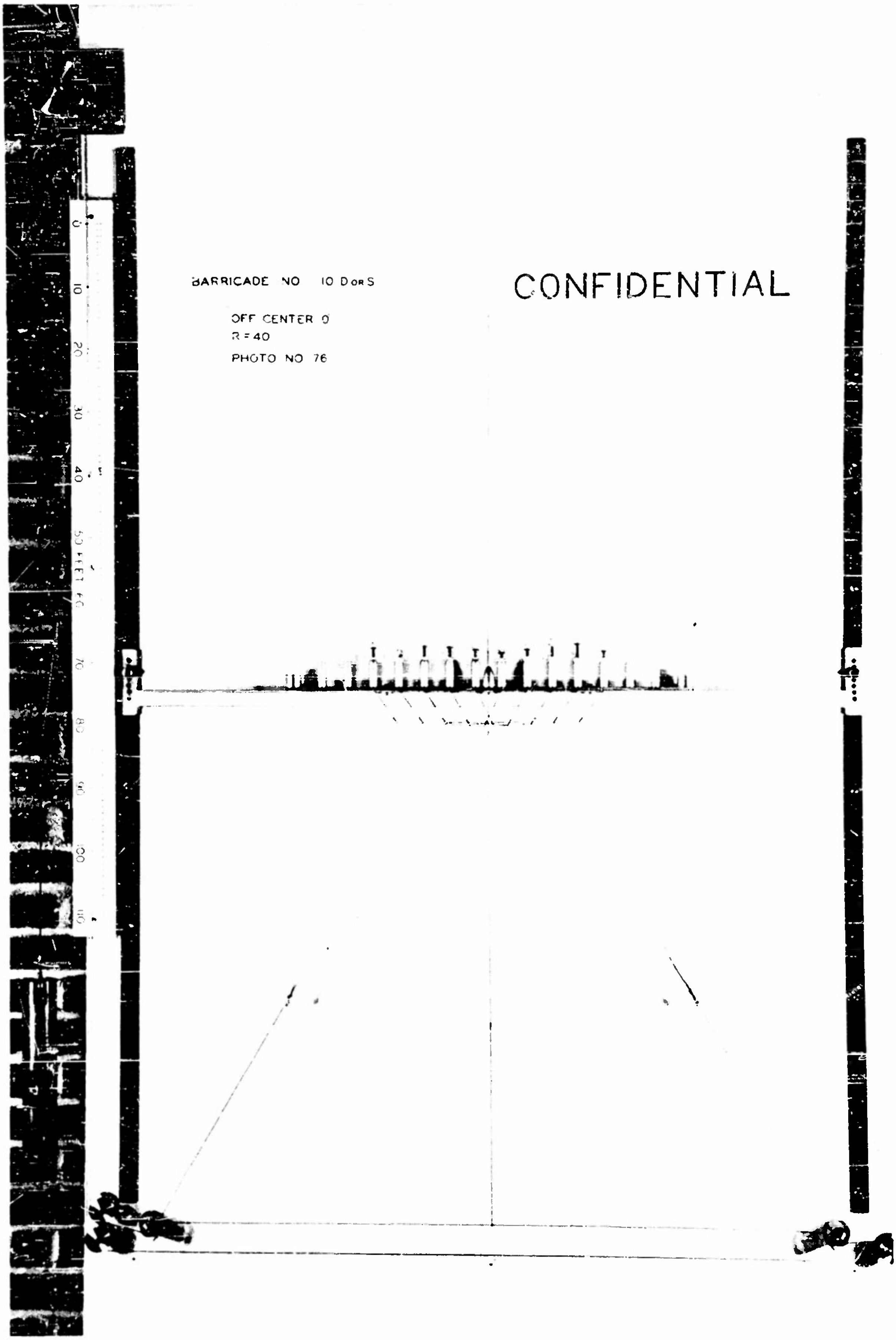
Believing that the information would be of value in judging the merits of a particular barricade, and of value in indicating the direction of possible modifications or even major changes in design, the present investigators undertook an extensive quantitative analysis of the force distributions in various types of barricades. An attempt to calculate the force distributions in possible barricade designs showed that although such calculations were often possible, they were long and tedious at best. An experimental approach was therefore adopted. It should be emphasized that all analyses made are for static conditions.

The group recognizes fully that appreciable differences would exist between static and dynamic analyses, and that a dynamic analysis would be much the more significant. Some serious difficulties which would have to be overcome in any dynamic model study are evident from NAMC Report #M-4601 entitled, "Scale Model Barrier Investigation." A further

analysis of conditions which must be met in dynamic model studies has convinced the present investigators that the added value of dynamic studies would scarcely warrant the time required to overcome the attendant difficulties, some of which it might well be impossible to overcome. Particularly is this true since one is interested mainly in comparing various designs. As long as considerations are confined to nylon or similar barricade material, as seems advisable on general grounds, this comparison can probably be made with sufficient reliability from static analyses.

There was constructed a model carrier landing deck with sheaves, purchase cable, and arresting engine which could simulate either a singly or a doubly reeved engine. All construction was to a scale of 3/8 inch to 1 foot. The general construction of the model, to which various barricades could be attached, is shown by the photograph on the following page (Photo No. 76). A 4-ft. x 8-ft. piece of plywood, with its length mounted vertically, was used as a landing deck. The deck sheaves were mounted 106 scale feet apart. The purchase cable was 36-lb. braided linen fish line held under a constant tension of 2,000 grams (when singly reeved) by a 4-kg. weight. There was negligible stretch in the linen purchase cable. The arrangement could be made to simulate a doubly reeved arresting engine simply by clamping the two parts of the purchase cable together back of the deck sheaves. Stops were mounted at the deck sheaves so that with zero runout the purchase cable extended 3 feet beyond each sheave. The arrangement therefore requires a barricade 100 feet long when in the mounted position.

Typical barricades have been constructed of 20-lb. nylon fish line. Upon being placed under tension, the initial stretch in this line is 1.2 per cent per lb. tension applied, or 24 per cent for a tension just less than that for rated failure. After the line is held in a stretched condition for some time the stretch is somewhat greater, approximately 1.7 per cent per lb. tension applied, or 34 per cent for a tension just less than that for rated failure. While the tensions in various members of the model barricades were far below the breaking strength of the line, they were sufficient to produce considerable stretch. Typical tensions encountered produced stretches of from 2 to 7 per cent. Stretch in an actual barricade would of course be much larger, but this would always lead to a more favorable distribution of forces. Attachment of the vertical elements of the barricade to the leading edge of the wing of the plane was at 4-ft. intervals. This attachment prohibited slippage of the vertical elements along the leading edge. Although simulation of the slippage encountered in an actual engagement would be desirable, the amount of slippage encountered is so variable that there seemed to be little use of attempting to simulate it. Adjustable screw mechanisms on the simulated plane wing allowed convenient adjustment of the lengths of the vertical elements. The position of the simulated plane could be adjusted to give any runout desired, or to correspond to landings


BARRICADE NO 10 D OR S
OFF CENTER 0
R = 40
PHOTO NO 76
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0
10
20
30
40
50 FEET 60
70
80
90
100
110

off center by any multiple of 4 feet. No provision exists for simulating a landing in which the axis of the fuselage is not parallel to the center-line of the deck, although in any complete study such a provision should be made.

Photographs of the barricade were taken on 35-mm. film at various stages of runout. These photographs were enlarged to 8" x 10" for the purpose of analysis. Whenever possible the forces in the various elements were determined graphically from these enlargements, and expressed as a ratio to T, where T is the tension in either purchase cable when the arresting engine is singly reeved. Analyses can be made rather rapidly. Errors in the graphical solution are usually only a few per cent, and rarely as large as 5 per cent. Many barricade structures have more than three forces acting at a given point, in which case knowledge of the tension in the purchase cable alone constitutes insufficient evidence to determine graphically (or even analytically) the forces in the individual elements of the barricade. In these cases the forces in the vertical elements were measured directly. The screw adjusting mechanism attaching the vertical element was designed to allow making such measurements simply by hooking a spring balance to the top of the mechanism. While direct measurements of force are less accurate than graphical determinations because of friction in the adjusting mechanism, they are sufficiently accurate to use when necessary.

No great attempt has been made to attain the maximum possible accuracy in evaluating forces. There are several reasons this attempt was not made.

1. Choice among barricades will in general depend upon major rather than minor differences.

2. Actual force distributions depend greatly upon the stretch which occurs in the elements of the barricade as these elements are placed under tension.

3. The purpose of these observations is mainly to illustrate what can be done toward evaluating certain characteristics of a particular barricade, and to indicate the more general features of force distribution.

Were it desired to study carefully the detailed characteristics of a certain type of barricade, the method could easily be improved in accuracy, the model modified to allow simulation of other types of landings, and the barricade material and the tension in the purchase cable chosen to simulate closely the stretching of the actual barricade.

A number of barricades have been studied, at various runouts, for center and for off-center landings, and for the arresting engine either singly or doubly reeved. While most of the studies have been with conventional straight-wing planes, a number have been with planes having wings swept back 45° or 60°.

More than 300 photographs have been taken. Many of these are included in this report. Several barricades have been studied even though it was recognized in advance that they were of poor design. Information on them was desired for the purpose of comparison, and in some instances the information is included in this report.

The remainder of this section will present information obtained on different types of barricades when engaging the wings of a conventional straight-wing plane. (Data having to do with planes having sweptback wings will be presented in a later section.) In connection with each type of barricade there will be included:

1. A diagram illustrating the structure of the barricade.

2. A series of photographs illustrating the behavior of the barricade, usually for various runouts, usually for both center and off-center landings, and occasionally for a doubly reeved as well as a singly reeved arresting engine.

3. Tables showing the distribution of forces in the vertical elements of the barricade, and giving information as to the maximum force in any vertical element, the most objectionable angle at which any vertical element pulls against the leading edge of the wing, the component of force with which the barricade pulls the plane toward the center line of the deck, and the torque exerted on the plane.

Many comparisons will be made and some conclusions drawn as first one and then another barricade is discussed. Conclusions of a more general character will be reserved for a separate section at the end of the report.

In discussing the several barricades, and in formulating the tabular data on each, the following meanings and conventions are attached to the symbols used.

Each photograph has assigned to it a number, as for example, "Photo No. 76."

A number is assigned each barricade, as for example, "Barricade No. 10."

S or D following the number of a barricade indicates, respectively, that the barricade is attached to a singly reeved or a doubly reeved engine.

T represents the tension in the purchase cable when the arresting engine is singly reeved. For a doubly reeved engine T is one-half the sum of the tensions in the port and starboard purchase cables.

R represents the runout, always in feet. It is the distance the purchase cable has been pulled out, not the distance the plane has moved after engaging the barricade. For an off-center landing with a singly reeved arresting engine the

runout on the port side and that on the starboard side are usually unequal. In such instances both runouts are given, the port side runout first. A runout R of 45-40 means that the purchase cable has been pulled out 45 feet on the port side and 40 feet on the starboard side.

F_1, F_2, F_3 - - - - F_{10} represent respectively the forces in the 10 vertical elements of the barricade engaged with the plane, starting always from the port side. All forces are specified relative to the tension T. For example, F_3/T = 0.20 means that the tension in the third vertical element from the port side engaged with the plane, is 0.20 times the tension provided in the purchase cable by a singly reeved arresting engine.

ϕ represents the angle between the force with which a vertical element pulls on the leading edge of the wing and a horizontal line drawn perpendicular to the leading edge.

F_c represents the component of force with which the barricade pulls on the plane in a direction perpendicular to the center line of the deck. A positive value indicates that this component of force is directed toward the center line; a negative value indicates that it is directed away from the center line.

The torque tending to rotate the plane about an axis perpendicular to the deck and passing through the center of gravity of the plane is taken as positive when this torque is in such a direction as to turn the nose of the plane toward the center line of the deck, and negative when it tends to turn the nose away from the center line. Torque/T is always expressed in feet. Its numerical value represents the length of the lever arm required if a force T is to produce this torque. In evaluating this torque it has been assumed (consistent with accepted methods of estimating) that for a straight-wing plane the center of gravity is located in the vertical plane in which the axis of the fuselage lies, and 2.5 feet behind the leading edge of the wing. It has been assumed that for a plane with wings swept back 45°, the center of gravity is 12.5 feet behind the intersection of the projections of the leading edges of the wings. It has been assumed that for a plane with wings swept back 60°, the center of gravity is 21 feet behind the intersection of the projections of the leading edges of the wings.

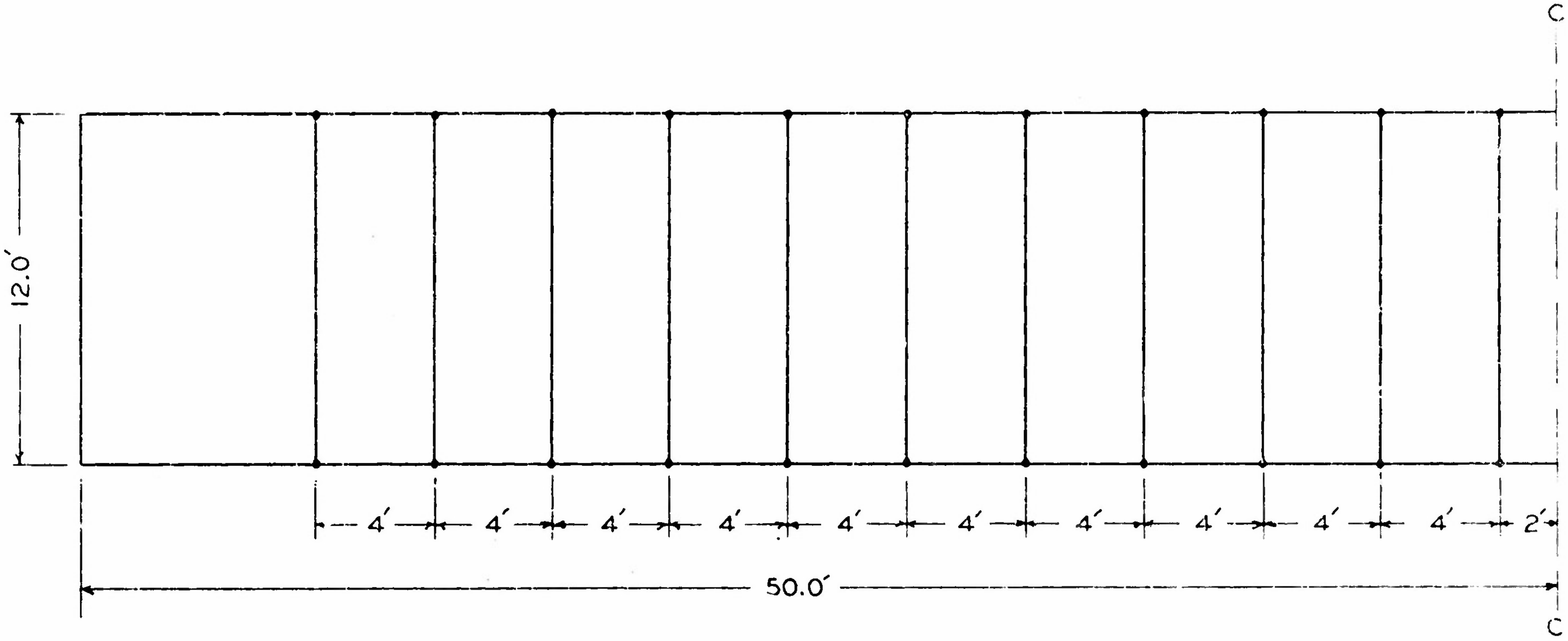
Barricade No. 1

Consider the very simple type of barricade shown on page 12. In the mounted position the bounding elements of the barricade constitute a rectangle (neglecting sag) 100 feet long and 12 feet high. Vertical elements are arranged 4 feet apart, their ends being fastened to the horizontal elements at the points of attachment. When the barricade folds over the plane it will assume a length of 112 feet from the point of attachment to the port purchase cable to the point of attachment to the starboard purchase cable.

The photographs on page 13 illustrate the behavior of this barricade. Photo No. 4 is for a center landing and a runout of 50 feet, the arresting engine being either singly or doubly reeved. Photo No. 15 is for a 16-foot off-center landing, a runout of 50 feet on the port side and 30 feet on the starboard side, the arresting engine being singly reeved. Photo No. 10 is for a 16-foot off-center landing and a runout of 45 feet on each side, the arresting engine being doubly reeved.

Data showing the behavior of this barricade are collected in the tables on pages 14-16. As could have been foreseen, even for a center landing (page 14) it is only the outer two elements that assume any appreciable fraction of the retarding force. This is true for all runouts. For large runouts the force in either outer element becomes essentially equal to the tension in the purchase cable. Much the same remarks can be made for a 16-foot off-center landing when the arresting engine is singly reeved (page 15).

For a 16-foot off-center landing with the arresting engine doubly reeved (page 16), the situation becomes extremely aggravated in several respects. For other than very small runouts, only the one vertical element farthest off center experiences any tension; the tension in this element reaches the maximum possible, 2T. There exists a considerable component of force pulling the plane away from the center line. There also exists an extremely large torque (-36 T) turning the plane away from the center line. The maximum possible torque is 36.4 T for a plane and barricade of the dimensions being considered.



BARRICADE NO. 1 DESIGN

SCALE 3/16″ = 1′

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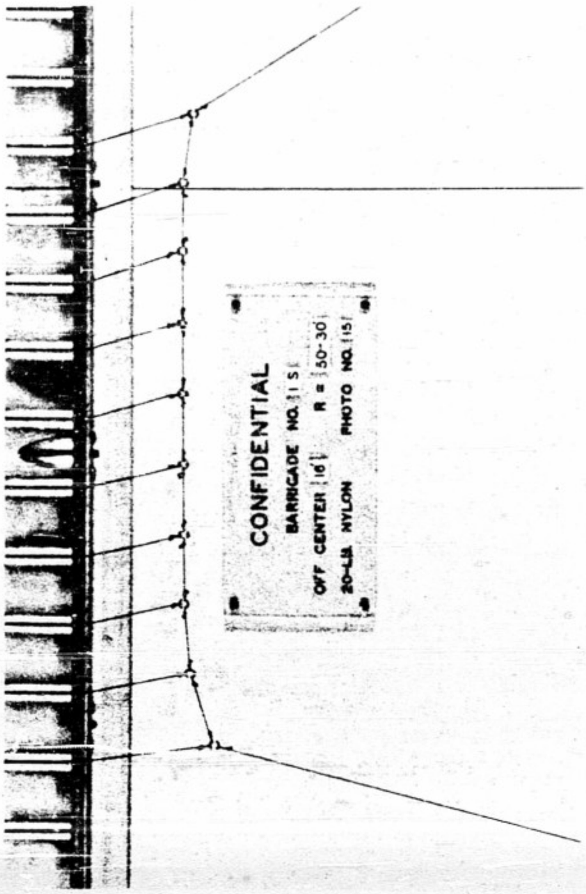
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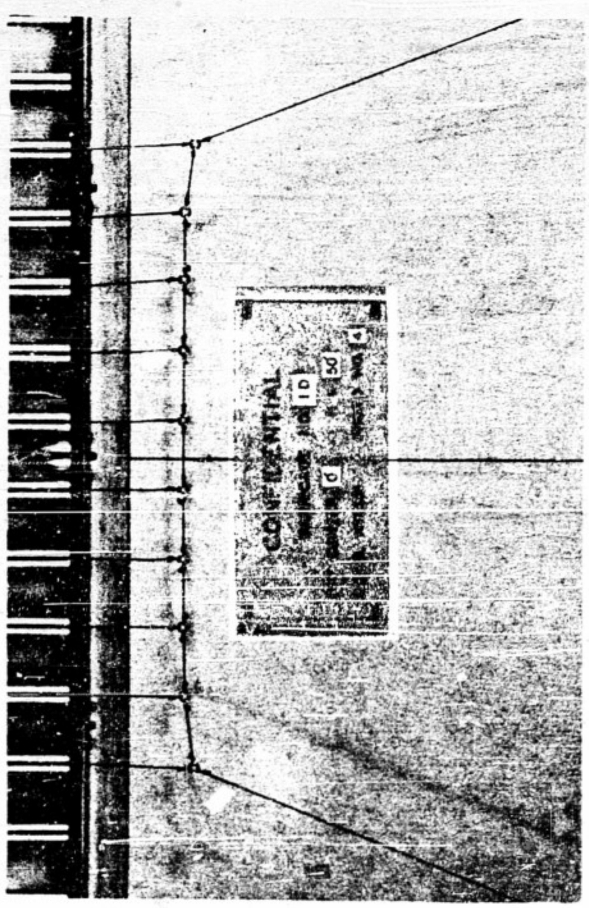
BARRICADE NO. 15
OFF CENTER 16'   R = 50-30'
20-LB. NYLON   PHOTO NO. 15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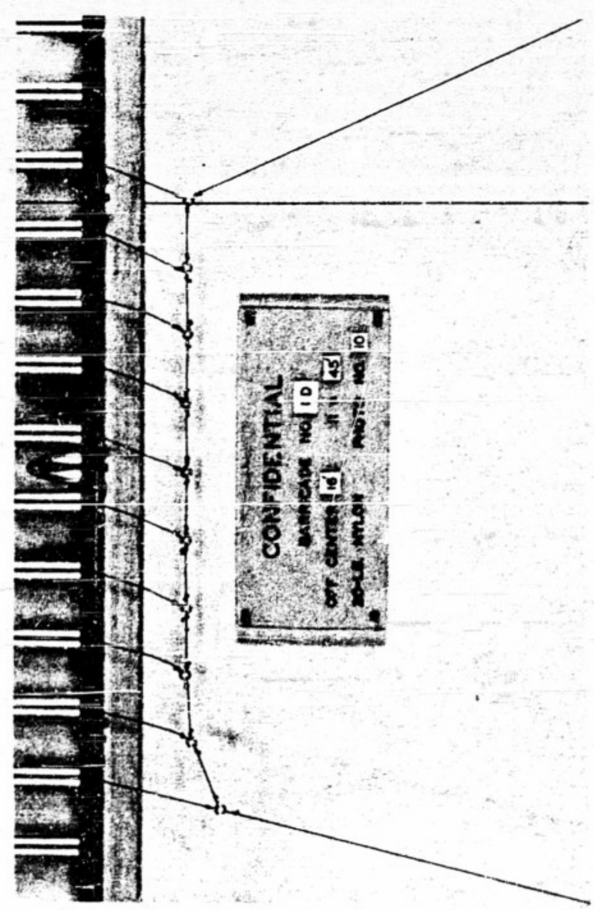
1D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BARRICADE NO. 1D
OFF CENTER 16'   45
20-LB. NYLON   PHOTO NO. 10

Barricade No. 1 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0	18	35	50	65	80
Photo No.	1	2	3	4	5	6
F_1/T	.57	.81	.84	.88	.89	.99
F_2/T	.02	.04	.03	.03	.03	.02
F_3/T	.02	.01	.01	.01	.01	.01
F_4/T	0	0	0	0	0	0
F_5/T	0	0	0	0	0	0
F_6/T	0	0	0	0	0	0
F_7/T	0	0	0	0	.01	0
F_8/T	.01	.01	.01	.01	.01	0
F_9/T	.04	.04	.04	.04	.04	.02
F_{10}/T	.58	.76	.87	.90	.94	.87
Max. ϕ	7°	6°	6°	3°	3°	2°
Element	#10	#10	#10	#10	#10	#1

Maximum F/T at any runout = 0.99

Maximum angle ϕ at any runout = 7°

F_o/T at 40-foot runout = 0

F_o/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 1 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0-0	10-0	30-13	50-30	70-48	90-66	110-85
Photo No.	19	13	14	15	16	17	18
F_1/T	.72	.71	.79	.71	.81	.84	.83
F_2/T	.08	.12	.10	.07	.06	.05	.04
F_3/T	.03	.04	.03	.02	.02	.02	.01
F_4/T	.01	.01	0	0	0	0	0
F_5/T	0	0	0	0	0	0	0
F_6/T	0	0	0	0	0	0	0
F_7/T	0	0	0	0	0	0	0
F_8/T	0	.01	.01	.01	.01	.01	0
F_9/T	.02	.05	.05	.04	.03	.03	.02
F_{10}/T	.14	.44	.76	.99	.97	.99	1.04
Max. ∅	16°	18°	18°	18°	15°	12°	11°
Element	#1	#10	#10	#10	#10	#10	#10

Maximum F/T at any runout = 1.04

Maximum angle ∅ at any runout = 18°

F_c/T at 40-foot runout = 0.44

F_c/T at 78-foot runout = 0.29

Torque/T at 40-foot runout = 4.5 ft.

Torque/T at 78-foot runout = 2.4 ft.

Barricade No. 1 D

Plane Wings Straight

Doubly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0	6	20	45	60	80
Photo No.	7	8	9	10	11	12
F_1/T	1.30	1.54	2.00	2.00	2.00	2.00
F_2/T	.07	.11	0	0	0	0
F_3/T	.02	.02	0	0	0	0
F_4/T	.01	.01	0	0	0	0
F_5/T	0	0	0	0	0	0
F_6/T	0	0	0	0	0	0
F_7/T	0	0	0	0	0	0
F_8/T	0	0	0	0	0	0
F_9/T	.02	.01	0	0	0	0
F_{10}/T	.16	.12	0	0	0	0
Max. ϕ	22°	22°	21°	14°	12°	10°
Element	#1	#1	#1	#1	#1	#1

Maximum F/T at any runout = 2.00

Maximum angle ϕ at any runout = 22°

F_o/T at 45-foot runout = -0.48

F_o/T at 80-foot runout = -0.33

Torque/T at 45-foot runout = -36 ft.

Torque/T at 80-foot runout = -36 ft.

Barricade No. 2A

There would be many advantages to a barricade, say of 10 vertical elements, in which the forces in all vertical elements were equal and in which all of these forces were parallel, each pulling directly backward on the plane. Such a barricade can be designed for a specified center or off-center landing and a specified runout. The design has been calculated for a center landing; the design is a function of the runout. The figures and tables on page 18 give the results for a number of different runouts. Although in all other instances throughout this report barricade dimensions are given for elements in the unstretched condition, in these tables and the diagram which follows them the dimensions given are for the elements stretched as they are in operation.

The design utilizes vertical elements the length of which is a function of the distance of the element from the center of the barricade. Although the barricade would be mounted in such a manner that the vertical elements engage the wing of the plane 4 feet apart, the distance between points of attachment of two successive elements to the longitudinal members is also a function of the distance from the center of the barricade. These functional relations can be expressed either graphically or analytically. They can then be used to obtain the design characteristics for any runout desired.

Barricade No. 2A, illustrated on page 19, was designed to equalize forces in the vertical elements and make them parallel for a runout of 40 feet. Behavior of the barricade for different runouts is shown by the series of photographs on page 20. Quantitative data are shown in the table on page 21. Note the equality of forces for a runout of 40 feet, one of the conditions which dictated the design. Note also from Photo No. 233, page 20, that the forces are essentially parallel, another condition which dictated the design. Note also (from the table) that the maximum F/T in any vertical element for any runout is only 0.37, a highly satisfactory value.

Attempts to extend this barricade for an off-center landing have led to no satisfactory design. The vertical elements become unduly long, and the best position to attach the vertical element soon falls beyond the end of the barricade. In spite of having some very favorable characteristics, this design does not appear promising.

$T_P + T_S = 2T$
$T_P = T_S = T$

$\theta_5 = \theta_P$
$\theta_6 = \theta_4$
$\theta_7 = \theta_3$
$\theta_8 = \theta_2$
$\theta_9 = \theta_1$

R = 0 θ_P = 30

N	θ_N	T_N/T	F_N/T	L_N	D_N
1	24.8	.95	.100	4.4	10.7
2	19.1	.92	.100	4.2	8.8
3	13.0	.89	.100	4.1	7.4
4	6.6	.87	.100	4.0	6.5
5	0	.86	.100	4.0	6.0

R = 6 θ_P = 40

N	θ_N	T_N	$T F_N$	$T L_N$	D_N
1	33.9	.92	.129	4.9	12.7
2	26.7	.86	.129	4.5	10.0
3	18.5	.81	.129	4.3	8.0
4	9.5	.78	.129	4.1	6.7
5	0	.77	.129	4.0	6.0

R = 16 θ_P = 50

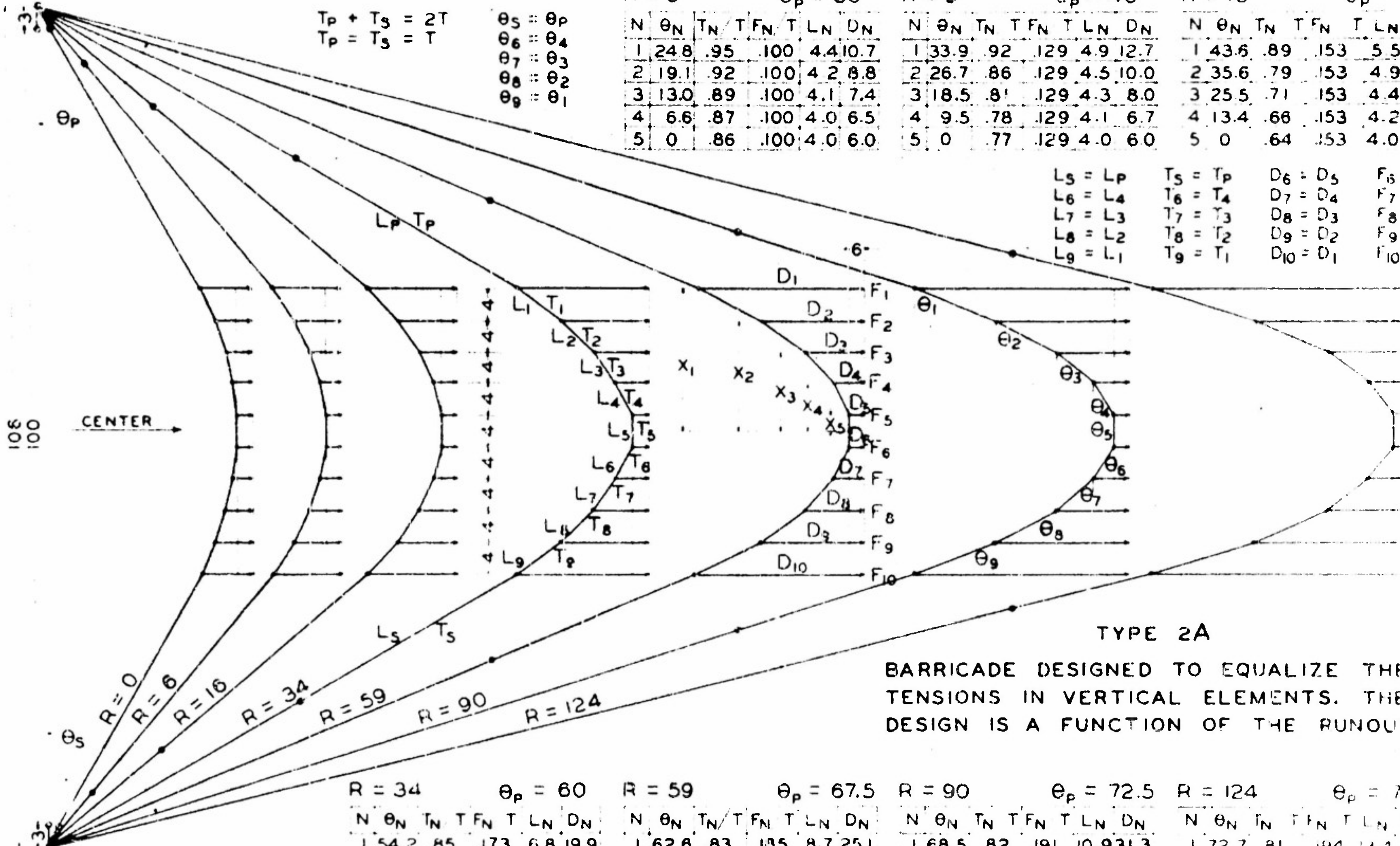
N	θ_N	T_N	$T F_N$	$T L_N$	D_N
1	43.6	.89	.153	5.5	15.5
2	35.6	.79	.153	4.9	11.7
3	25.5	.71	.153	4.4	8.8
4	13.4	.66	.153	4.2	6.9
5	0	.64	.153	4.0	6.0

$L_5 = L_P$
$L_6 = L_4$
$L_7 = L_3$
$L_8 = L_2$
$L_9 = L_1$

$T_5 = T_P$
$T_6 = T_4$
$T_7 = T_3$
$T_8 = T_2$
$T_9 = T_1$

$D_6 = D_5$
$D_7 = D_4$
$D_8 = D_3$
$D_9 = D_2$
$D_{10} = D_1$

$F_6 = F_5$
$F_7 = F_4$
$F_8 = F_3$
$F_9 = F_2$
$F_{10} = F_1$



TYPE 2A

BARRICADE DESIGNED TO EQUALIZE THE TENSIONS IN VERTICAL ELEMENTS. THE DESIGN IS A FUNCTION OF THE RUNOUT.

R = 34 θ_P = 60

N	θ_N	T_N	$T F_N$	$T L_N$	D_N
1	54.2	.85	.173	6.8	19.9
2	46.1	.72	.173	5.7	14.3
3	34.7	.61	.173	4.8	10.2
4	19.1	.53	.173	4.2	7.4
5	0	.50	.173	4.0	6.0

R = 59 θ_P = 67.5

N	θ_N	T_N/T	F_N	$T L_N$	D_N
1	62.6	.83	.185	8.7	25.1
2	55.4	.67	.185	7.0	17.3
3	44.0	.53	.185	5.6	11.5
4	25.8	.42	.185	4.4	7.7
5	0	.38	.185	4.0	6.0

R = 90 θ_P = 72.5

N	θ_N	T_N	$T F_N$	$T L_N$	D_N
1	68.5	.82	.191	10.9	31.3
2	62.3	.65	.191	8.6	21.2
3	51.7	.49	.191	6.5	13.6
4	32.3	.36	.191	4.7	8.5
5	0	.30	.191	4.0	6.0

R = 124 θ_P = 76

N	θ_N	T_N	$T F_N$	$T L_N$	D_N
1	72.7	.81	.194	13.4	38.2
2	67.4	.63	.194	10.4	25.3
3	58.1	.46	.194	7.6	15.7
4	38.7	.31	.194	5.2	9.2
5	0	.24	.194	4.0	6.0

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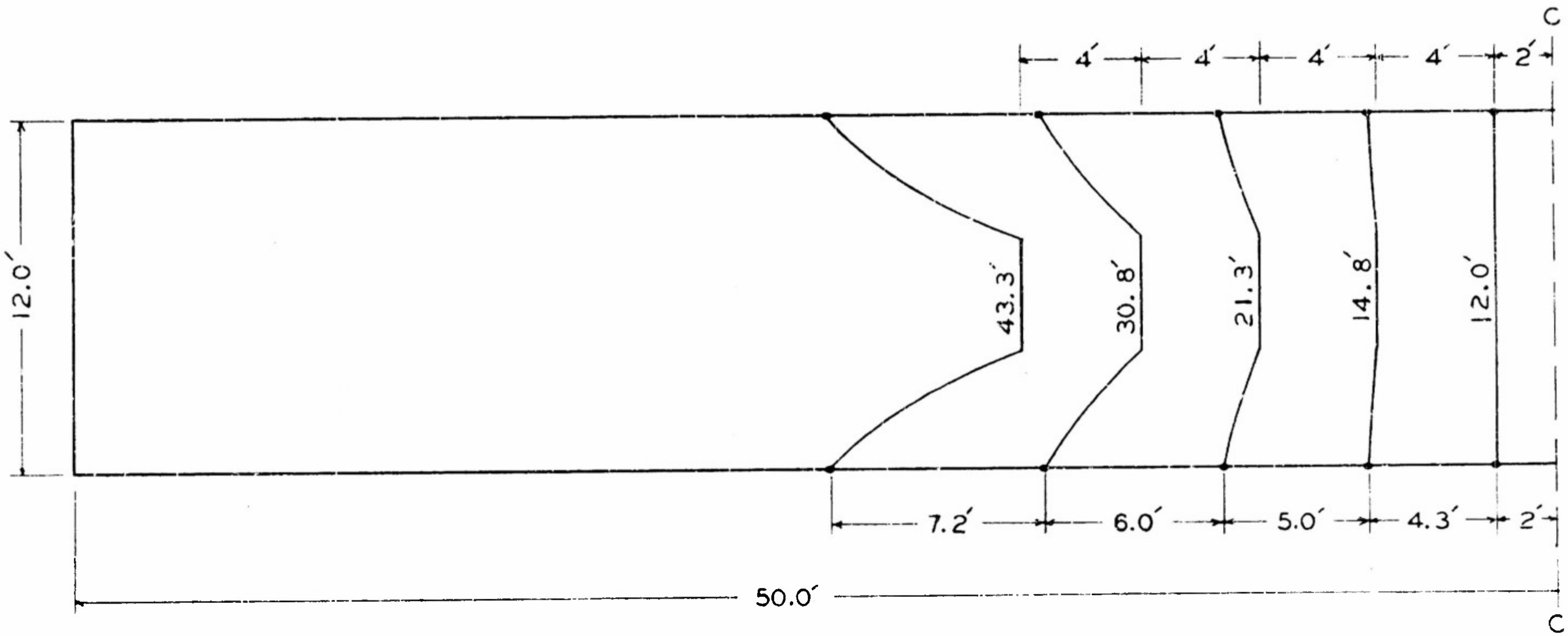
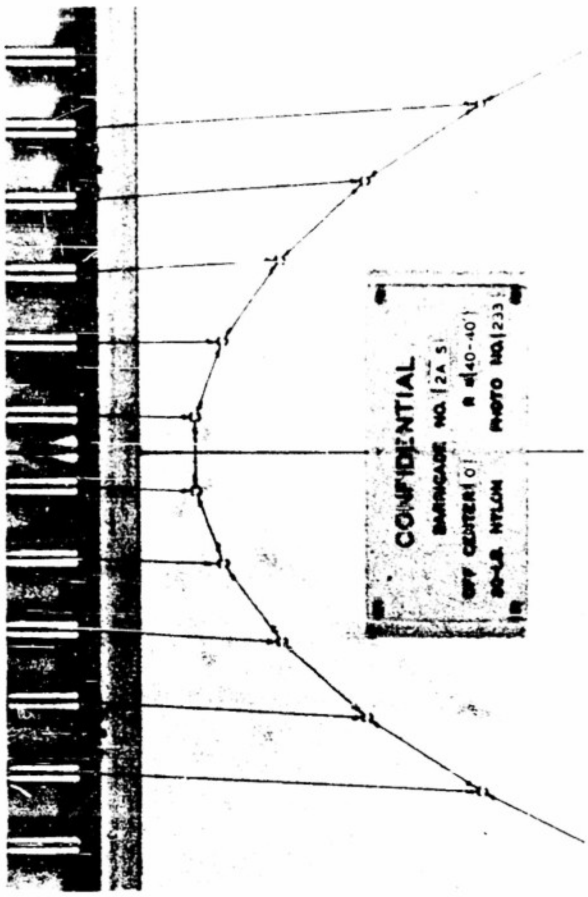
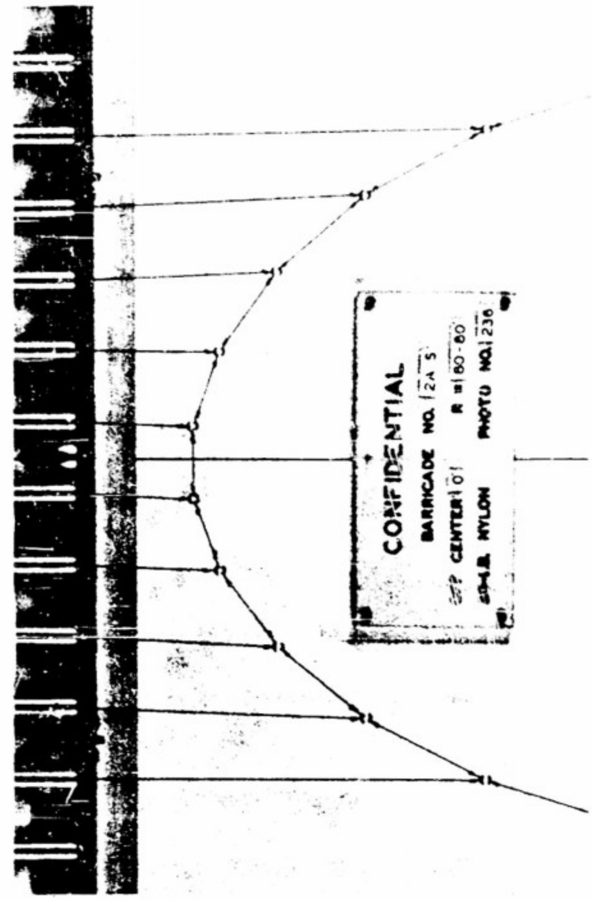


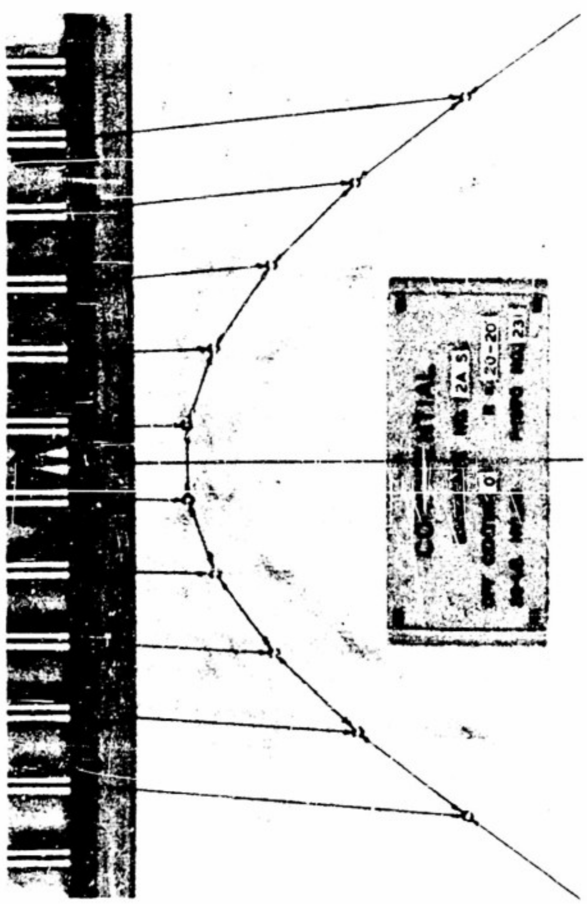
BARRICADE NO. 2A DESIGN

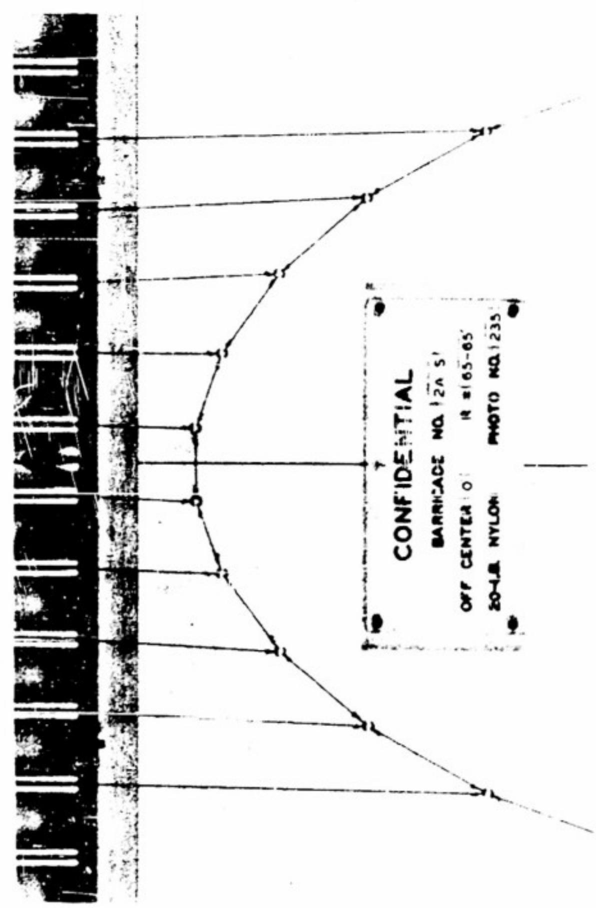
SCALE 3/16″ = 1′

CONFIDENTIAL


CONFIDENTIAL
BARRICADE NO. 2A 5
OFF CENTER 0'
R = 40-40'
20-LB. NYLON
PHOTO NO. 233


CONFIDENTIAL
BARRICADE NO. 2A 5
OFF CENTER 0'
R = 80-80
20-LB. NYLON
PHOTO NO. 236


2A 5
0'
R = 20-20'
231


CONFIDENTIAL
BARRICADE NO. 2A 5
OFF CENTER 0'
R = 65-65'
20-LB. NYLON
PHOTO NO. 235

Barricade No. 2A S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1-1	10-10	20-20	30-30	40-40	50-50	65-65	80-80
Photo No.	229	230	231	232	233	234	235	236
F_1/T	0	0	.05	.16	.17	.28	.34	.37
F_2/T	0	.06	.15	.18	.17	.21	.21	.21
F_3/T	.01	.19	.19	.18	.17	.15	.13	.12
F_4/T	.19	.21	.19	.17	.17	.13	.11	.10
F_5/T	.24	.22	.19	.17	.16	.13	.11	.09
F_6/T	.24	.22	.19	.17	.16	.13	.11	.09
F_7/T	.19	.21	.18	.17	.16	.12	.10	.09
F_8/T	.02	.19	.19	.18	.17	.15	.13	.12
F_9/T	0	.07	.17	.18	.17	.21	.21	.20
F_{10}/T	0	0	.08	.17	.18	.29	.34	.37
Max. ϕ	4°	5°	4°	4°	4°	4°	4°	3°
Element	#3	#2	#1	#2	#3	#3	#3	#3

Maximum F/T at any runout = 0.37

Maximum angle ϕ at any runout = 5°

F_c/T at 40-foot runout = 0

F_c/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

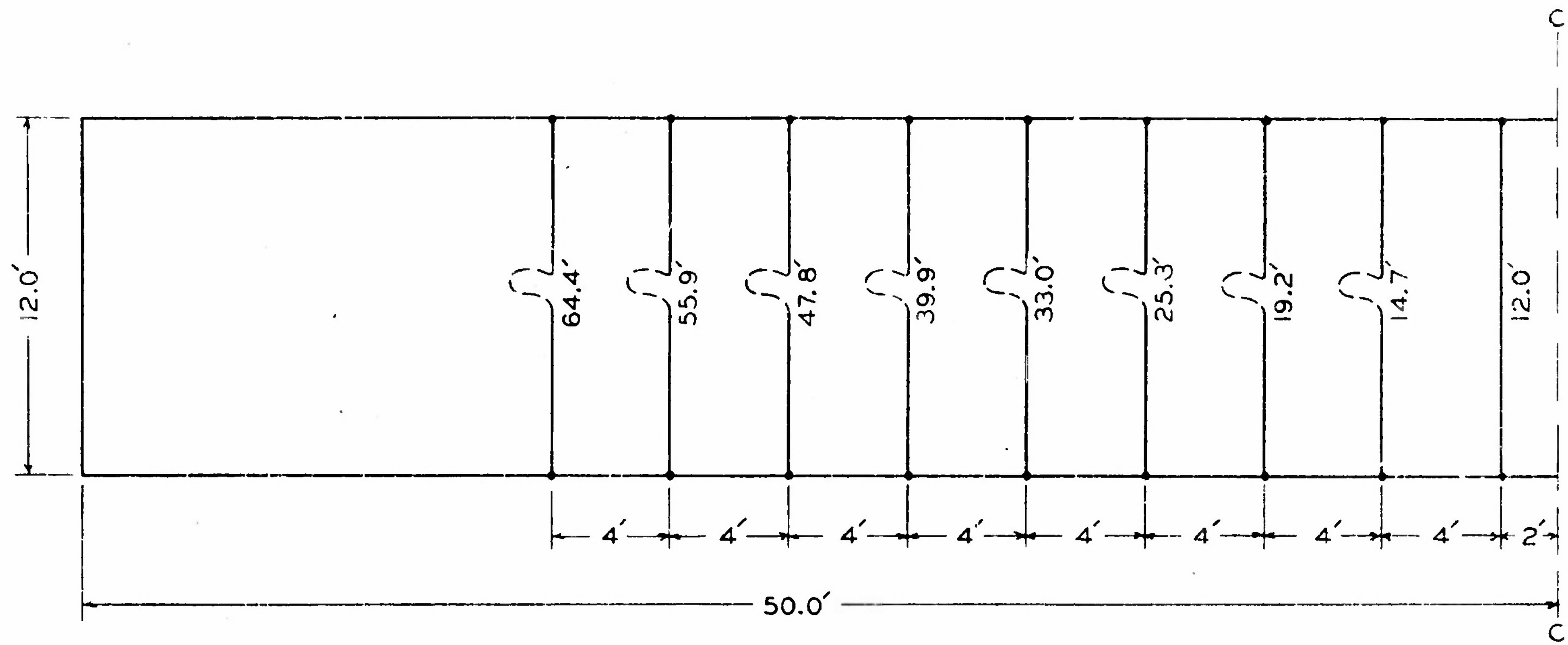
Barricade No. 2

By giving up one feature of Barricade No. 2A, that of parallel forces pulling directly backward on the plane, one can avoid the use of exceptionally long vertical elements and spacings between successive points of attachment so great as to be objectionable. Barricade No. 2 was therefore constructed with unequal length vertical elements attached at equal 4-foot intervals. It is possible to adjust the lengths of the vertical elements so the forces these elements exert are equal, though not parallel, for any desired runout. The design leading to equal forces for a center landing and a runout of 40 feet was determined by trial. The design dimensions are shown in the diagram on page 23.

The behavior of this barricade for a center landing is shown by the series of photographs on page 24, and by the data on page 26. Note the approximate equality of forces for a runout of 40 feet. Note also that the maximum value of F/T is 0.36, a highly satisfactory value.

One would suspect that it would be impossible to add elements to accommodate a 16-foot off-center landing and still maintain equal forces. The lack of success is shown by the series of photographs on page 25 and the data on page 27. The barricade is entirely unsatisfactory for an off-center landing.

The principal reason for studying this barricade was the hope that a compromise between it and a good off-center design might yield a barricade reasonably satisfactory for either a center or an off-center landing. Barricades Nos. 3, 4, 5, 6 and 7 were combinations which analyses showed to be unsatisfactory. They are not described here. Barricade No. 8, which does offer some promise of satisfactory combination with No. 2, will be described.



BARRICADE NO. 2 DESIGN

SCALE 3/16″ = 1′

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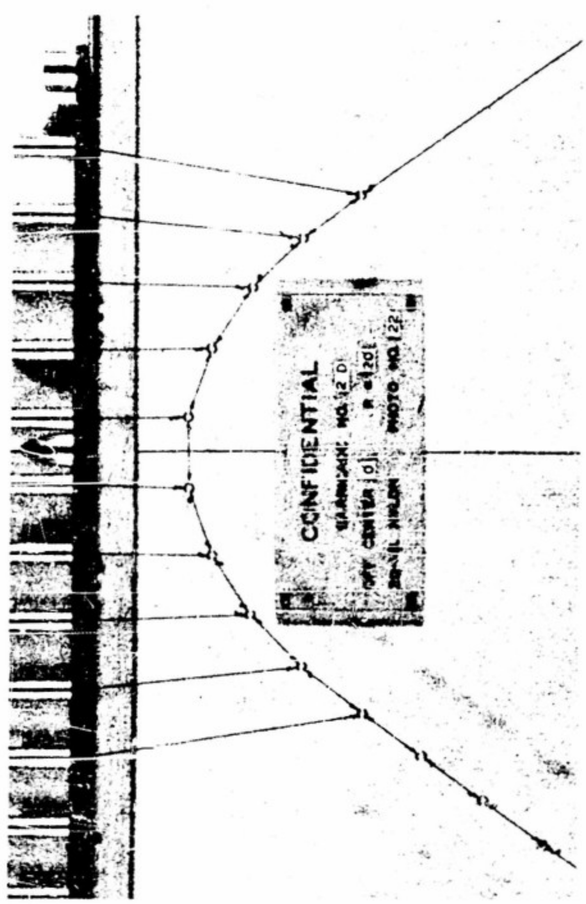
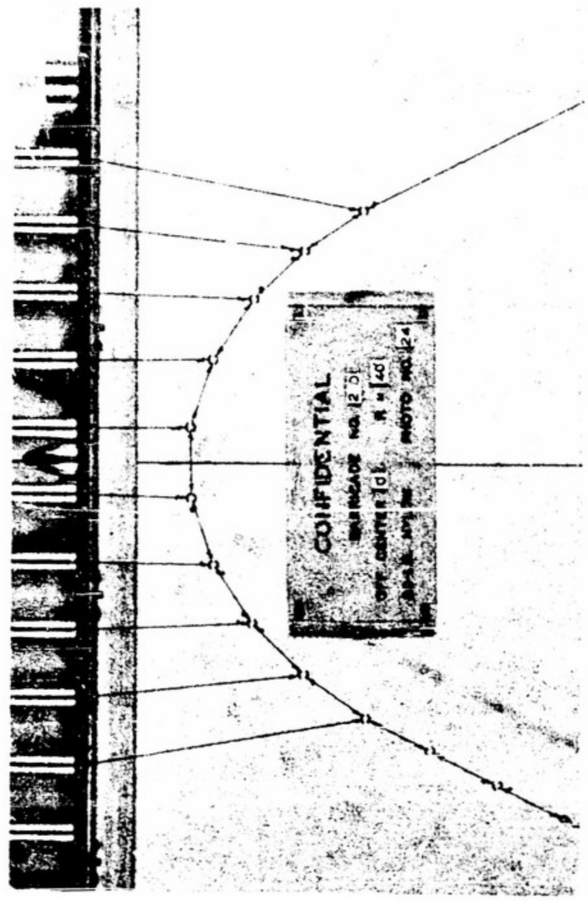
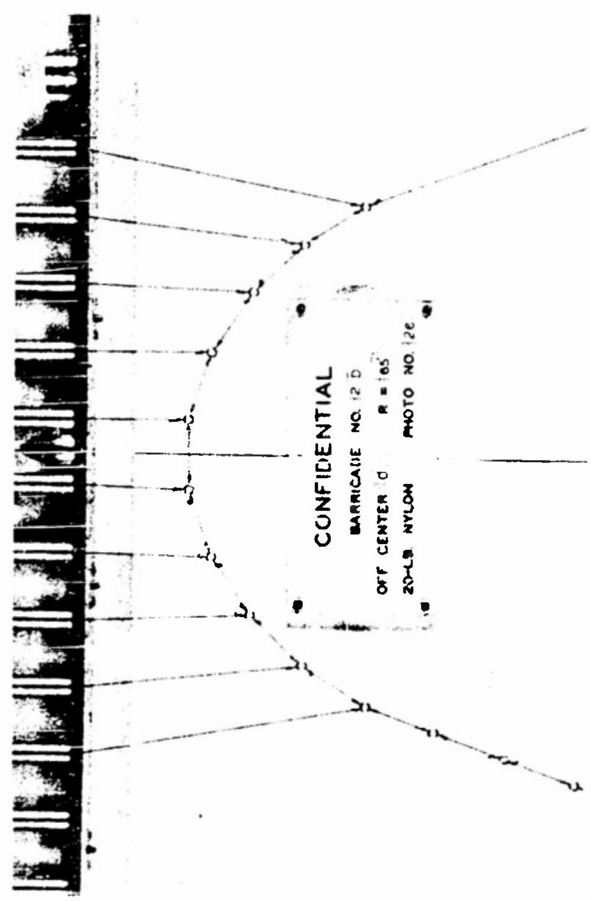
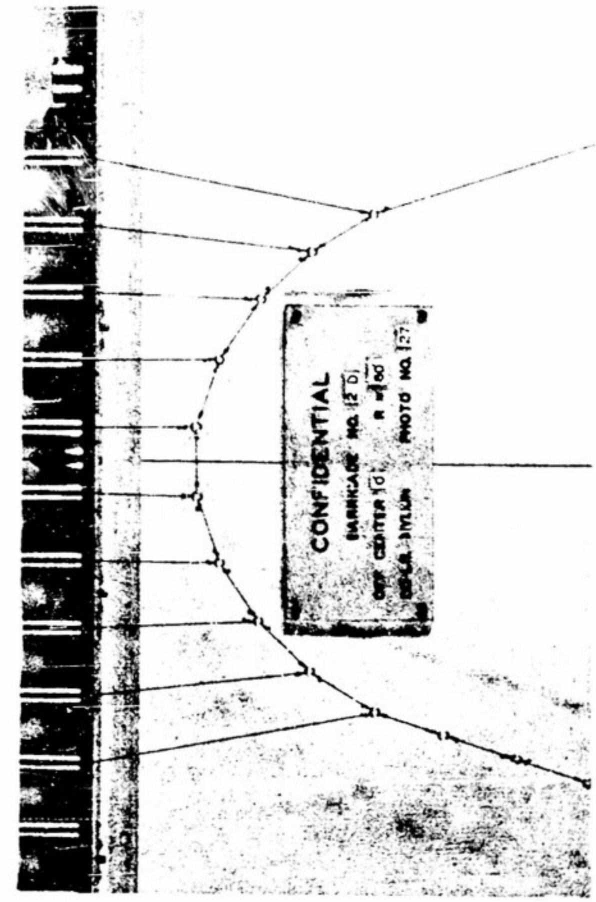
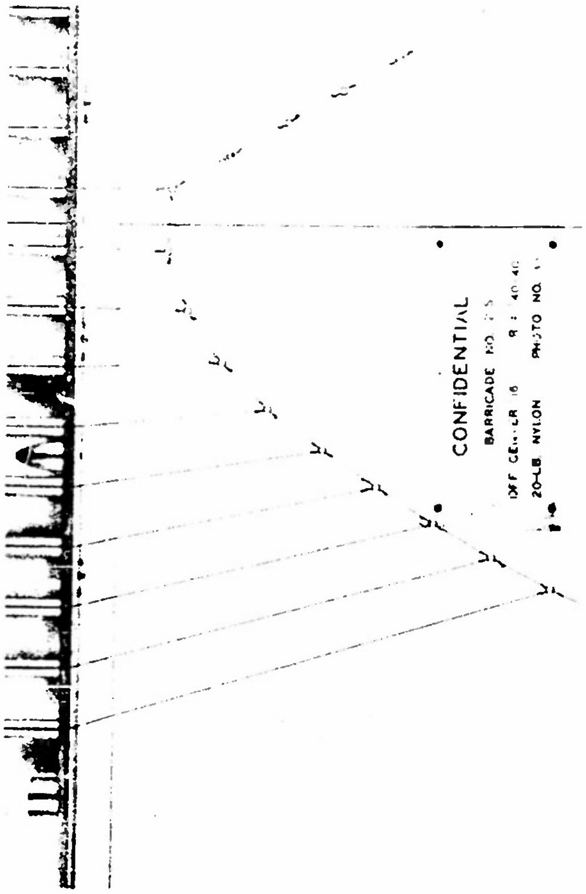

CONFIDENTIAL
BARRICADE NO. 12 D
OFF CENTER d R = 120
20-LB. NYLON PHOTO NO. 122


CONFIDENTIAL
BARRICADE NO. 12 D
OFF CENTER d R = 140
PHOTO NO. 124


CONFIDENTIAL
BARRICADE NO. 12 D
OFF CENTER d R = 165
20-LB. NYLON PHOTO NO. 128


CONFIDENTIAL
BARRICADE NO. 12 D
OFF CENTER d R = 160
20-LB. NYLON PHOTO NO. 127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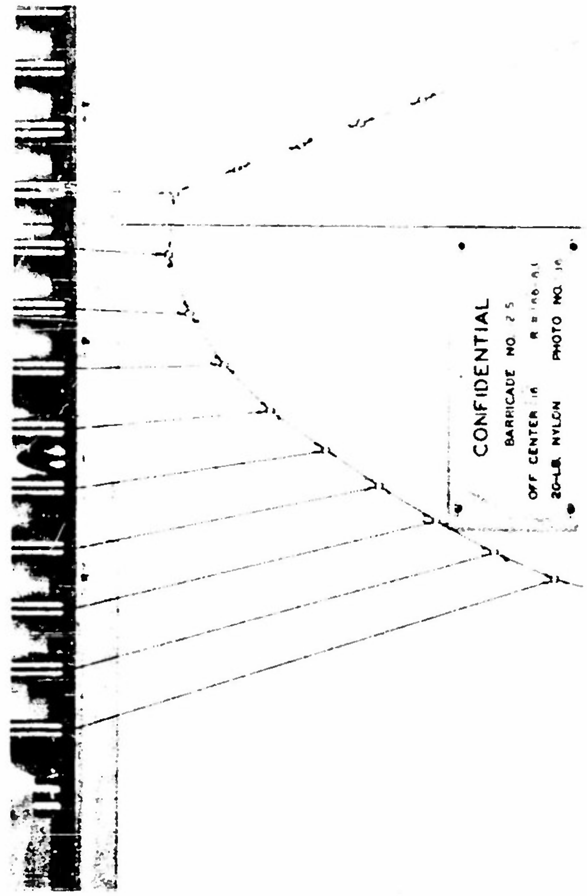
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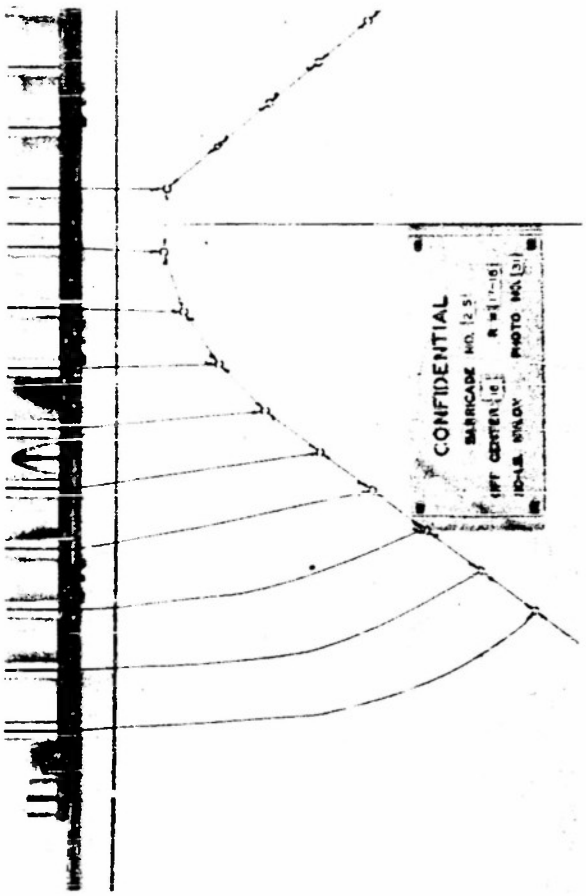
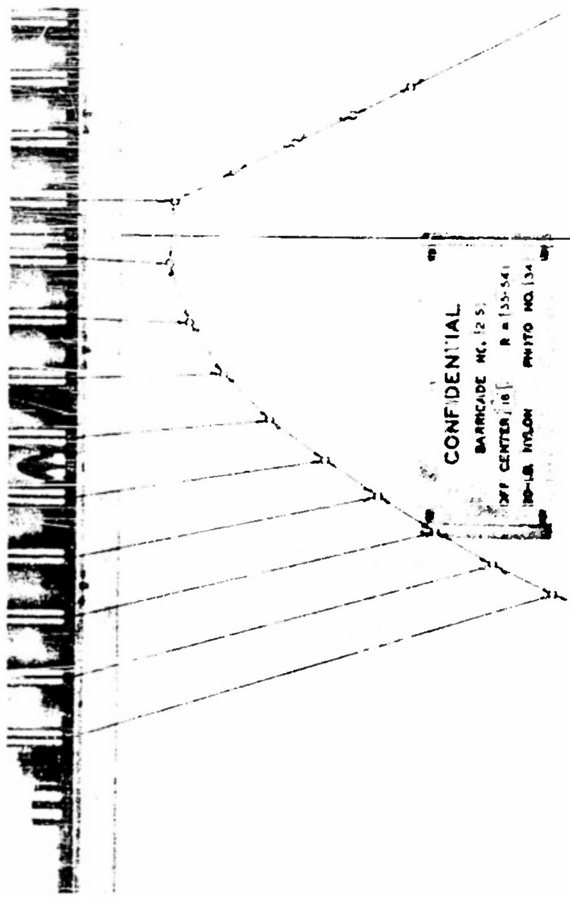

CONFIDENTIAL


CONFIDENTIAL

Barricade No. 2 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0	6	20	30	40	50	65	80
Photo No.	20	21	22	23	24	25	26	27
F_1/T	0	0	.05	.14	.20	.27	.32	.36
F_2/T	0	.01	.18	.17	.20	.21	.20	.21
F_3/T	.07	.19	.19	.17	.17	.16	.14	.19
F_4/T	.25	.23	.19	.17	.17	.15	.13	.18
F_5/T	.25	.24	.19	.18	.16	.15	.14	.17
F_6/T	.28	.25	.21	.20	.18	.16	.15	.15
F_7/T	.23	.22	.19	.19	.17	.16	.14	.13
F_8/T	.06	.19	.21	.18	.18	.17	.15	.15
F_9/T	0	.01	.14	.18	.18	.18	.18	.19
F_{10}/T	0	0	.05	.13	.19	.21	.31	.35
Max. ϕ	3°	3°	6°	9°	10°	10°	10°	11°
Element	#5	#5	#2	#10	#10	#10	#10	#10

Maximum F/T at any runout = 0.36

Maximum angle ϕ at any runout = 11°

F_c/T at 40-foot runout = 0

F_c/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 2 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0-0	6-7	17-18	26-26	40-40	55-54	71-69	86-83
Photo No.	29	30	31	32	33	34	35	36
F_1/T	0	0	0	0	.10	.16	.21	.23
F_2/T	0	0	0	.02	.05	.09	.09	.12
F_3/T	0	0	0	.02	.04	.04	.05	.05
F_4/T	0	0	0	.05	.05	.06	.05	.05
F_5/T	0	0	.01	.03	.02	.03	.03	.02
F_6/T	0	.03	.20	.18	.17	.14	.14	.13
F_7/T	.05	.19	.20	.18	.16	.14	.14	.12
F_8/T	.24	.23	.20	.19	.16	.15	.14	.13
F_9/T	.30	.27	.24	.22	.20	.18	.18	.16
F_{10}/T	.56	.65	.69	.77	.80	.84	.90	.90
Max. ø	4°	2°	5°	6°	17°	18°	18°	19°
Element	#10	#7	#6	#6	#1	#1	#1	#1

Maximum F/T at any runout = 0.90

Maximum angle ø at any runout = 19°

F_c/T at 40-foot runout = 0.07

F_c/T at 84-foot runout = 0.11

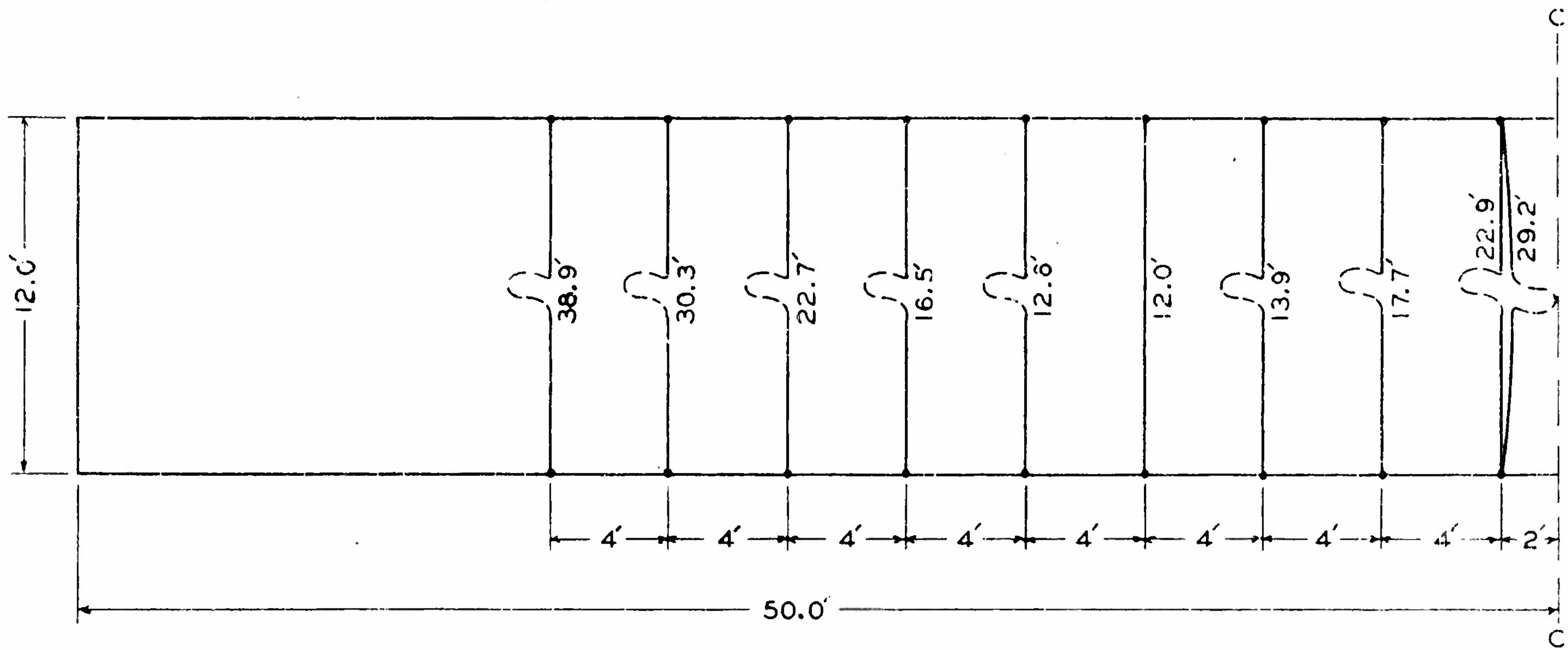
Torque/T at 40-foot runout = 17 ft.

Torque/T at 84-foot runout = 14 ft.

Barricade No. 8

Barricade No. 8 was designed by trial to give equal forces in the vertical elements for a 16-foot off-center landing and a runout of 40 feet. The design is shown on page 29. The vertical element on either side of center must be double in order to provide equally well for a 16-foot off-center landing to the port or starboard side. The series of photographs on page 30 and the table on page 31 show that the barricade is quite satisfactory for a 16-foot off-center landing. No observations were made for a center landing; it is obvious that the behavior would have been poor.

It is possible that a satisfactory barricade having double or even triple vertical elements could be designed. If double elements were used, one set might be proper for a center landing and the other set proper for a 16-foot off-center landing. As individual elements not designed for a particular landing accept too large a tension, they fail, leaving still operative the elements designed for this landing. Since Barricade No. 2 was highly satisfactory for a center landing and No. 8 quite satisfactory for a 16-foot off-center landing, there is some hope that a double barricade of the two would be satisfactory for either landing. It is this combination that is represented by Barricade No. 9.



BARRICADE NO. 8 DESIGN

SCALE 3/16" = 1'

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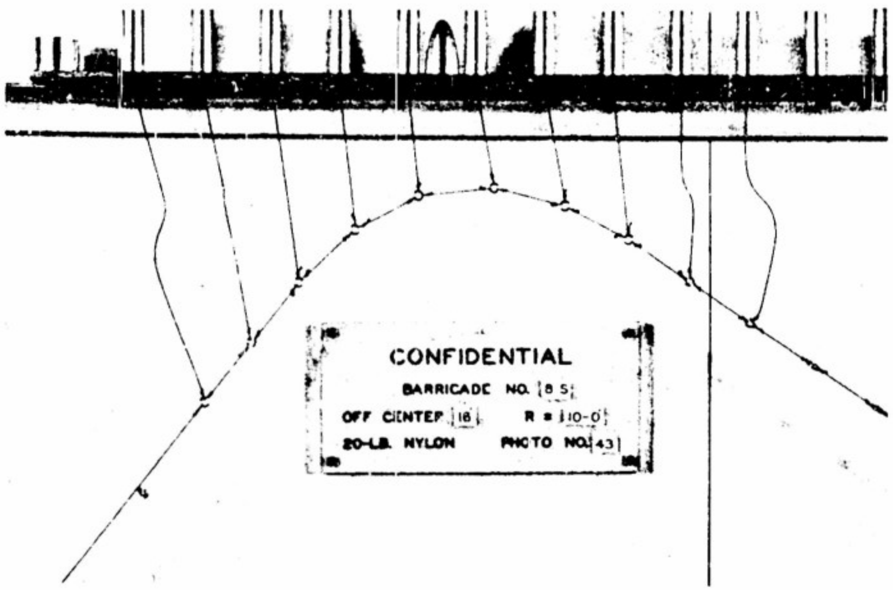
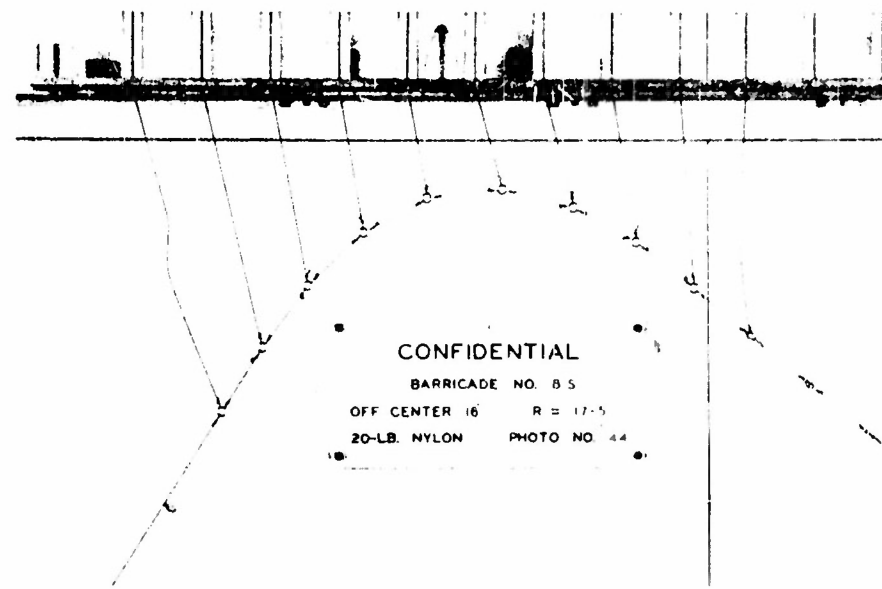

CONFIDENTIAL
BARRICADE NO. 8.5
OFF CENTER 16 R = 110-0
20-LB. NYLON PHOTO NO. 43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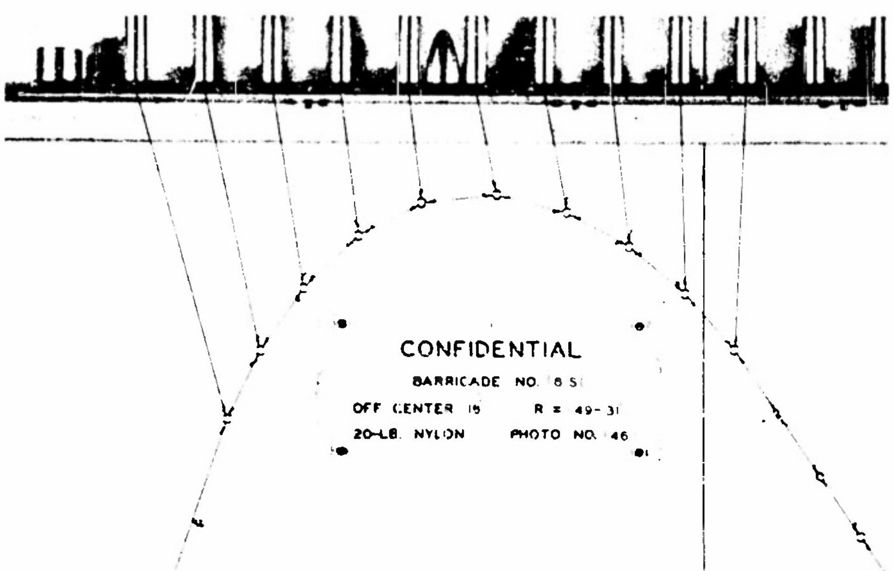
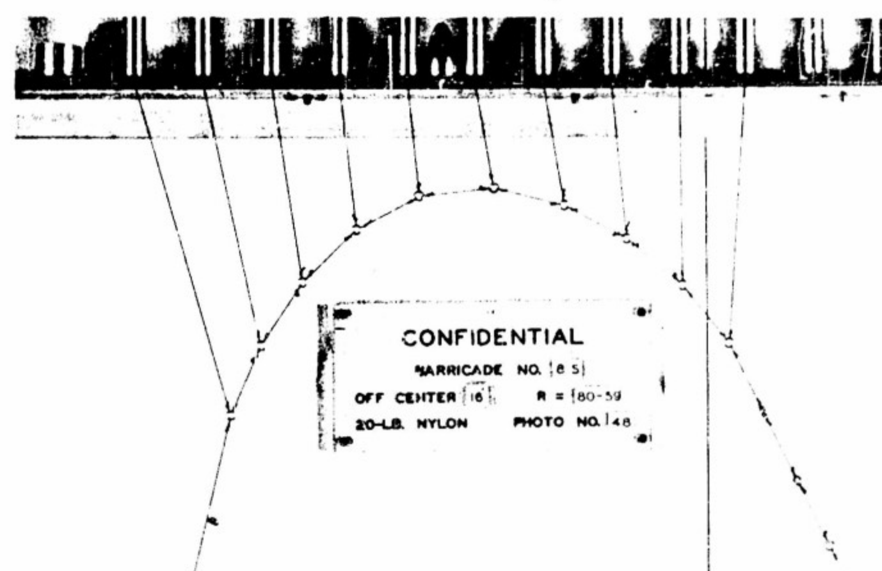
BARRICADE NO. 8.5
OFF CENTER 16 R = 17-5
20-LB. NYLON PHOTO NO. 44


CONFIDENTIAL
BARRICADE NO. 8.5
OFF CENTER 16 R = 49-31
20-LB. NYLON PHOTO NO. 46


CONFIDENTIAL
BARRICADE NO. 8.5
OFF CENTER 16 R = 80-59
20-LB. NYLON PHOTO NO. 48

Barricade No. 8 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0-0	10-0	17-5	36-20	49-31	64-45	80-59	95-73
Photo No.	42	43	44	45	46	47	48	49
F_1/T	0	0	0	.12	.19	.25	.28	.31
F_2/T	0	0	.09	.17	.18	.19	.20	.21
F_3/T	.03	.18	.19	.19	.17	.16	.16	.15
F_4/T	.33	.25	.24	.20	.18	.16	.15	.14
F_5/T	.36	.27	.26	.20	.19	.17	.16	.15
F_6/T	.16	.27	.26	.21	.18	.17	.16	.14
F_7/T	.07	.22	.21	.19	.18	.15	.14	.13
F_8/T	.01	.12	.11	.19	.17	.15	.14	.13
F_9/T	0	0	0	.16	.18	.18	.18	.20
F_{10}/T	0	0	0	.08	.18	.27	.34	.38
Max. ø	22°	11°	16°	16°	16°	16°	17°	17°
Element	#4	#6	#4	#1	#1	#1	#1	#1

Maximum F/T at any runout = 0.38

Maximum angle ø at any runout = 22°

F_o/T at 40-foot runout = 0.24

F_o/T at 84-foot runout = 0.20

Torque/T at 40-foot runout = 0.5 ft.

Torque/T at 84-foot runout = 1.2 ft.

Barricade No. 9

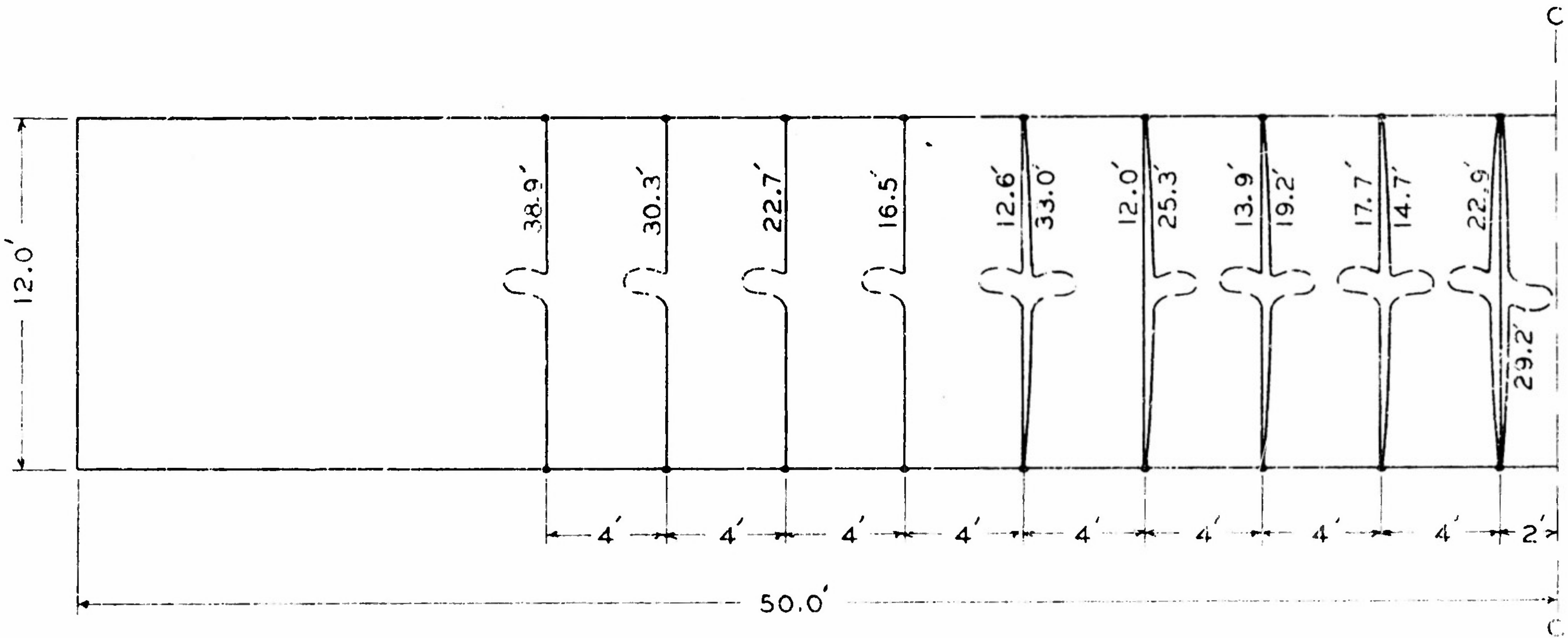
Barricade No. 9 consists in general of double vertical elements, as shown in the diagram on page 33. One set corresponds to the elements of No. 2, correct for a center landing and a runout of 40 feet. The other set corresponds to the elements of No. 8, correct for a 16-foot off-center landing and a runout of 40 feet. The element on either side of center is triple; it was double in No. 8. The four elements shown on the left are single; these are never engaged in a center landing.

The series of photographs on page 34 and the table on page 36 show the behavior of this barricade for a center landing. The photographs are so chosen as to show that those vertical elements not appropriate for a center landing break at very small runouts. It can be seen from the table on page 26 that no vertical element designed for a center landing need ever be subjected to a force greater than that corresponding to F/T = 0.36. Similarly, from the table on page 31, no element designed for a 16-foot off-center landing need ever be subjected to a force greater than that corresponding to F/T = 0.38. It was therefore assumed arbitrarily that an element fails when the force in it reaches a value corresponding to F/T = 0.40. The element was cut to simulate breaking. By comparing Photo Nos. 209 and 213 on page 34, it is seen that all elements which ever fail do so before the runout has exceeded one foot. The table on page 36 shows that after these elements fail the barricade behaves quite satisfactorily for a center landing.

Although no series of photographs is reproduced for a 16-foot off-center landing, the table on page 38 shows that the three elements which do break fail at very small runouts. After these failures the barricade is quite satisfactory for a 16-foot off-center landing.

The question of how good or how poor this barricade would be for an 8-foot off-center landing is answered by Photo No. 216 on page 35 and the table on page 37. The behavior is certainly not good; those vertical elements farthest from center take an undue share of the load. The series of photographs on page 35, all for a 40-foot runout, shows the relative behavior of this barricade for a center landing, an 8-foot off-center landing and a 16-foot off-center landing.

It appears probable that a reasonably satisfactory distribution of forces could be obtained for any off-center landing up to 24 feet if one were willing to construct a triple element barricade.



BARRICADE NO. 9 DESIGN

SCALE 3/16" = 1'

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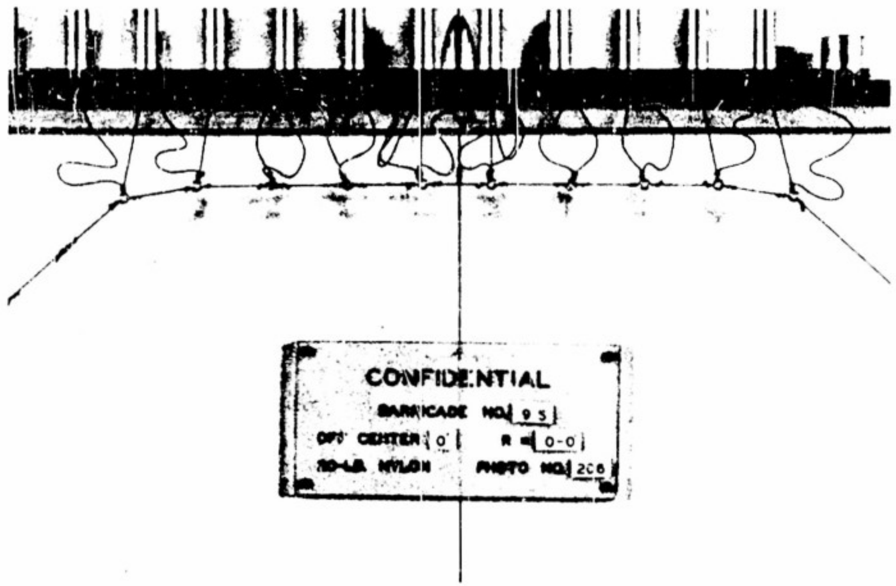
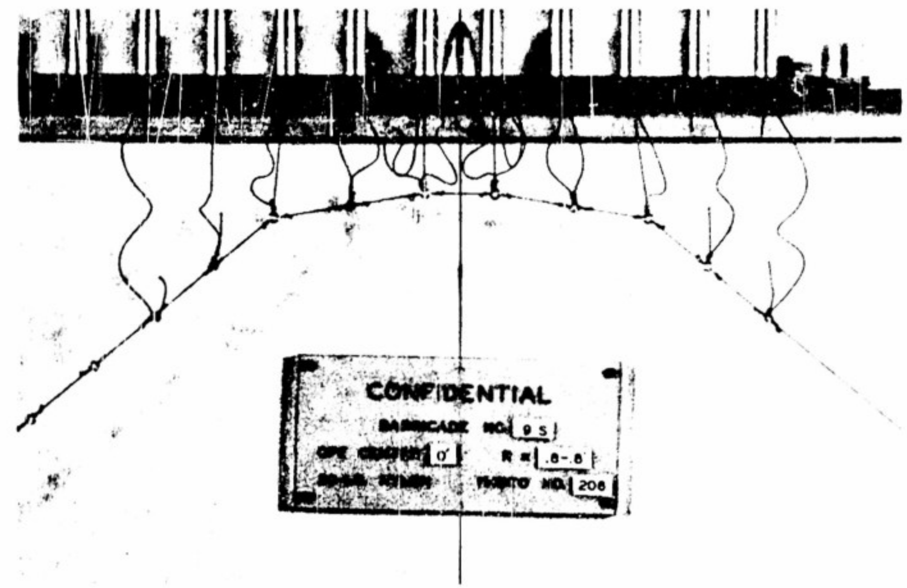
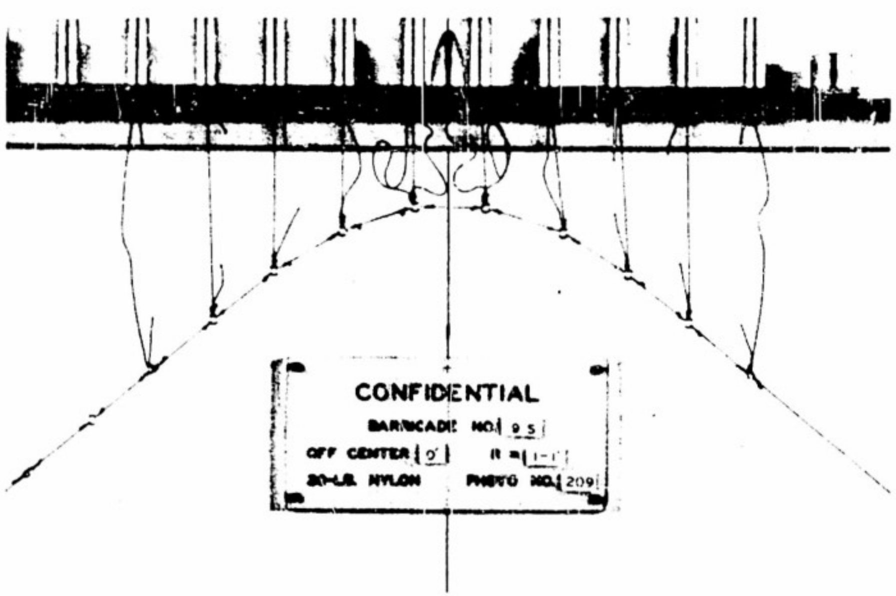
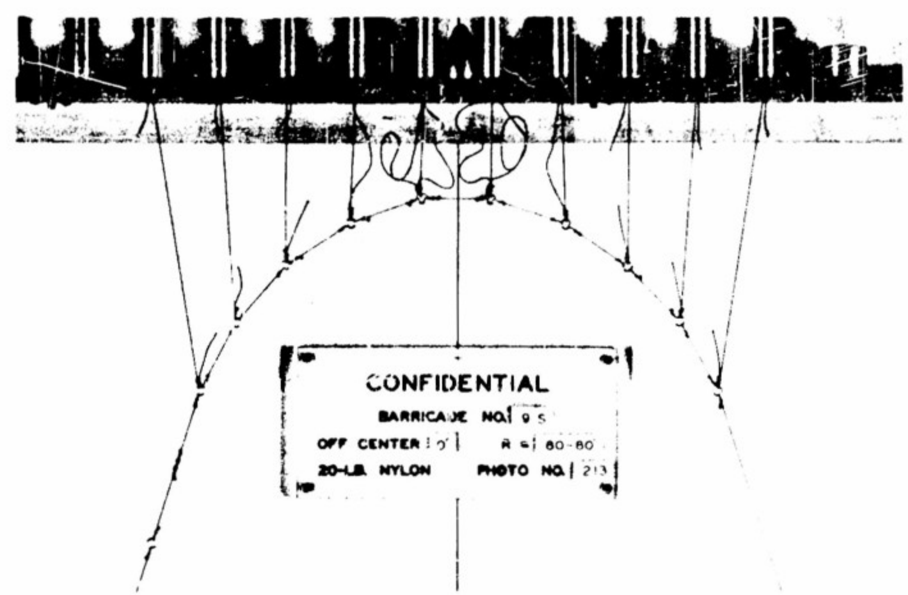
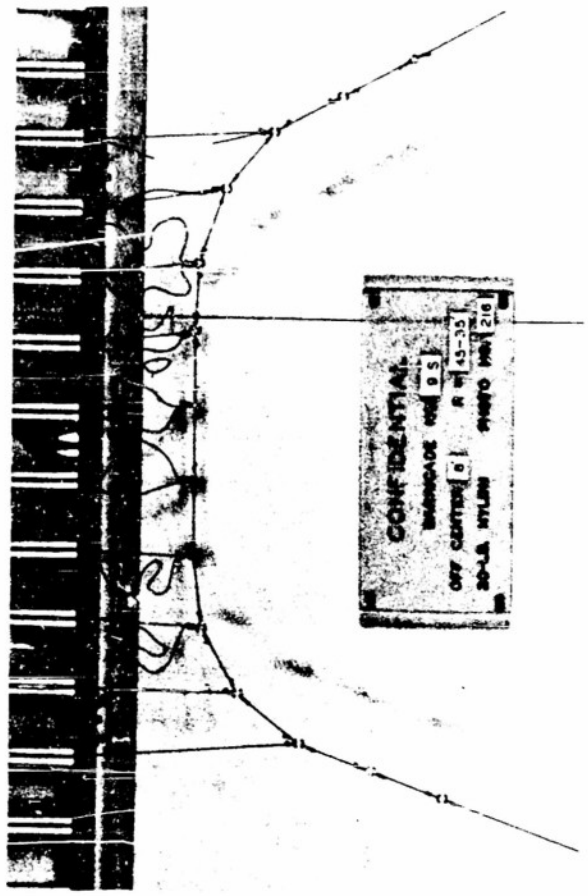
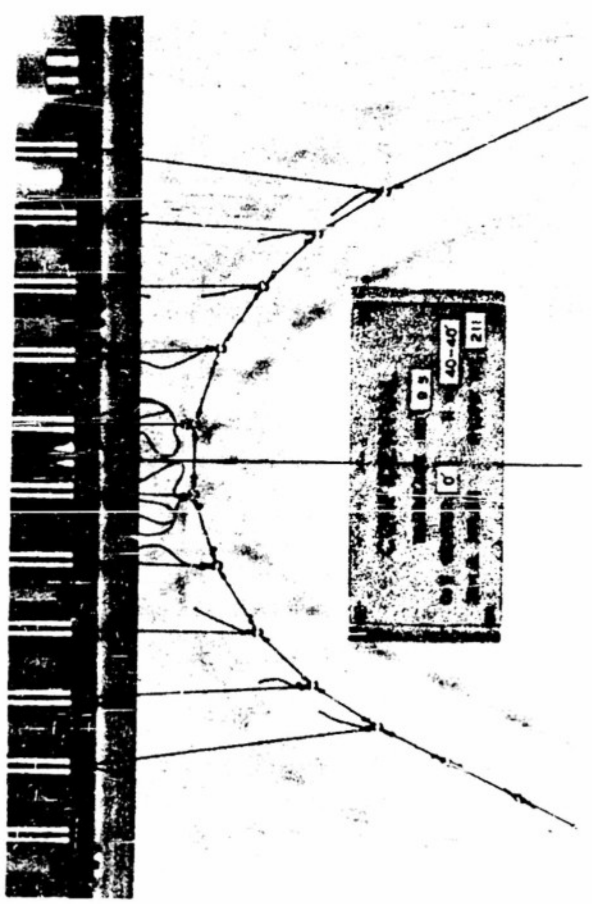

CONFIDENTIAL
BARRICADE NO. 9 5
OFF CENTER 0' R = 0-0
NYLON PHOTO NO. 206

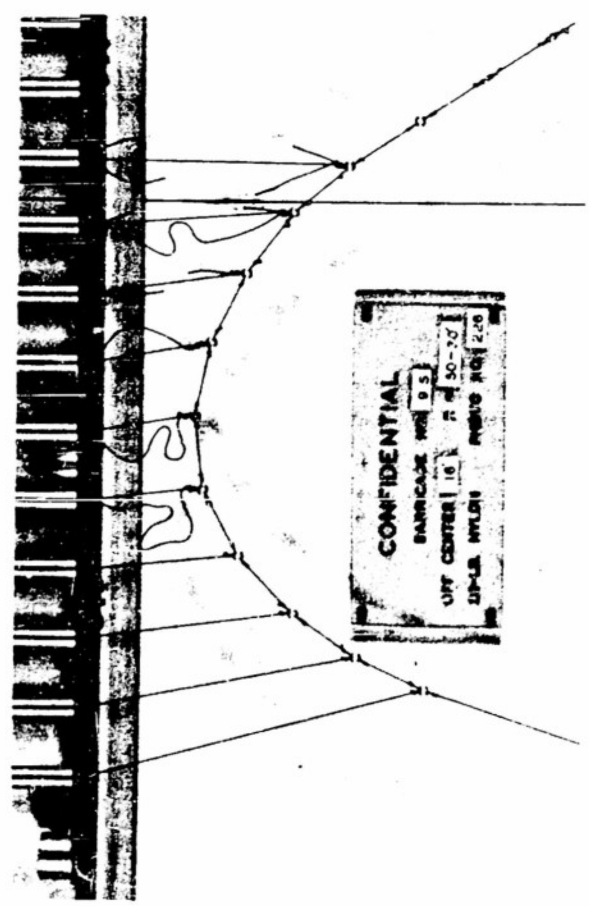

CONFIDENTIAL
BARRICADE NO. 9 5
0' R = .8-.8
PHOTO NO. 206


CONFIDENTIAL
BARRICADE NO. 9 5
OFF CENTER 0' R = 1-1
20-LB. NYLON PHOTO NO. 209


CONFIDENTIAL
BARRICADE NO. 9 5
OFF CENTER 0' R = 80-80
20-LB. NYLON PHOTO NO. 213


CONFIDENTIAL
BARRICADE
OFF CENTER 6'
R 45-35
PHOTO 216


40-40
211


CONFIDENTIAL
BARRICADE 9 5
OFF CENTER 16'
PHOTO NO

Barricade No. 9 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	0-0	.5-.5	.8-.8	1-1	20-20	40-40	65-65	80-80
Photo No.	206	207	208	209	210	211	212	213
F_1/T	.52	0	0	0	.04	.20	.30	.34
F_2/T	.10	.70	0	0	.19	.23	.23	.24
F_3/T	0	0	.52	.13	.20	.19	.16	.15
F_4/T	0	0	0	.24	.20	.16	.14	.13
F_5/T	.01	.03	.16	.25	.18	.16	.14	.13
F_6/T	.01	.03	.16	.25	.19	.15	.13	.12
F_7/T	0	0	0	.23	.18	.15	.13	.12
F_8/T	0	0	.52	.14	.20	.18	.15	.16
F_9/T	.10	.70	0	0	.18	.22	.22	.22
F_{10}/T	.52	0	0	0	.03	.19	.30	.32
Max. ϕ	11°	6°	5°	3°	4°	9°	10°	10°
Element	#1	#2	#7	#7	#2	#1	#1	#1

Maximum F/T at any runout = 0.34

Maximum angle ϕ at any runout = 11°

F_c/T at 40-foot runout = 0

F_c/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 9 S

Plane Wings Straight

Singly Reeved
8-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	24-16	45-35	71-59	86-74
Photo No.	215	216	217	218
F_1/T	.31	.45	.53	.57
F_2/T	.25	.26	.24	.25
F_3/T	.18	.15	.13	.13
F_4/T	.06	.05	.04	.03
F_5/T	0	0	0	0
F_6/T	0	0	0	0
F_7/T	.02	.02	.02	.02
F_8/T	.15	.11	.10	.10
F_9/T	.24	.23	.22	.23
F_{10}/T	.30	.46	.60	.65
Max. ϕ	10°	9°	9°	8°
Element	#9	#9	#9	#9

Maximum F/T at any runout = 0.65

Maximum angle ϕ at any runout = 10°

F_e/T at 40-foot runout = -0.14

F_e/T at 80-foot runout = -0.11

Torque/T at 40-foot runout = -0.4 ft.

Torque/T at 80-foot runout = 0.3 ft.

Barricade No. 9 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	7-.5	8-.8	10-.9	13-1	29-11	50-30	77-53	91-69
Photo No.	220	221	222	224	225	226	227	67
F_1/T	0	0	0	0	.10	.22	.28	.32
F_2/T	0	0	.02	.01	.15	.17	.19	.19
F_3/T	.15	.20	.22	.22	.22	.21	.19	.18
F_4/T	.23	.21	.21	.22	.17	.15	.13	.12
F_5/T	.28	.27	.26	.27	.22	.19	.16	.15
F_6/T	.08	.10	.23	.26	.20	.17	.14	.13
F_7/T	0	0	0	.20	.17	.14	.12	.10
F_8/T	0	0	.43	.19	.22	.20	.19	.16
F_9/T	.03	.57	0	0	.13	.14	.18	.16
F_{10}/T	.56	0	0	0	.06	.21	.34	.40
Max. ø	12°	11°	11°	13°	15°	16°	16°	16°
Element	#10	#9	#8	#7	#1	#1	#1	#1

Maximum F/T at any runout = 0.40

Maximum angle ø at any runout = 16°

F_c/T at 40-foot runout = 0.24

F_c/T at 80-foot runout = 0.21

Torque/T at 40-foot runout = 0.3 ft.

Torque/T at 80-foot runout = 1.5 ft.

Barricade No. 10

The next barricade studied, No. 10, was of a design essentially the same as the barricade now in use on carriers. Its basic construction is shown by the diagram on page 41. There are five independent longitudinal elements. The vertical elements are free to slide along the longitudinal elements, each fifth vertical element being attached to the same pair of longitudinal elements.

The behavior of this barricade for a center landing, a 16-foot off-center landing and a 24-foot off-center landing, always with the arresting engine singly reeved, is illustrated by the series of photographs on pages 42, 43 and 44. The photographs on page 45 illustrate comparative behavior for a center landing, an 8-foot off-center landing, a 16-foot off-center landing and a 24-foot off-center landing. Numerical data relative to this barricade, attached to a singly reeved arresting engine, are given in the tables on pages 47-50.

The series of photographs on page 46 illustrates the behavior of this barricade for a 16-foot off-center landing when the barricade is attached to a doubly reeved arresting engine. Similar photographs have been taken for a 24-foot off-center landing, again with the arresting engine doubly reeved. Data for the barricade when attached to a doubly reeved arresting engine are shown in the tables on pages 51 and 52.

The following comments are offered:

1. For a center landing the distribution of forces among the vertical elements is highly satisfactory, and the maximum F/T in any element is 0.30 (page 47). This maximum F/T is slightly less than that for Barricade No. 9 for a center landing. For Barricade No. 9 the maximum F/T was 0.34 (page 36).

2. The angle ϕ, the angle between the force in a vertical element and a line drawn backward and perpendicular to the leading edge of the wing, is often rather large, even for a center landing. It reaches a maximum of 37° (page 47). This introduces considerable tendency for the vertical element to slip along the leading edge of the wing, thus inviting damage to both the element and the plane. In this respect Barricade No. 10 is considerably less satisfactory than No. 9, for which the maximum angle ϕ was 11° (page 36).

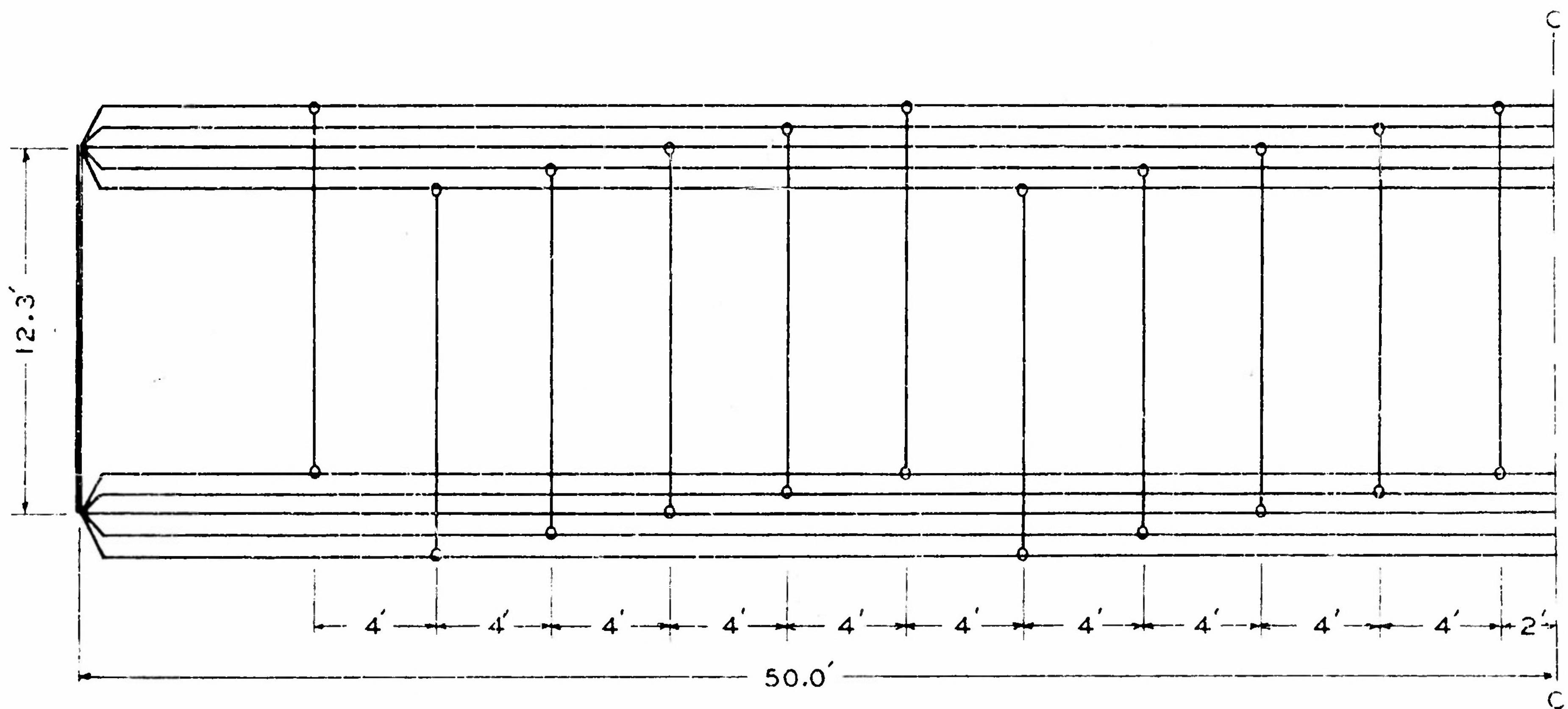
3. For a 16-foot off-center landing the forces are still distributed reasonably well, though by no means as satisfactorily as for a center landing. In this instance those elements farthest from the center of the landing deck suffer much the greater tensions (page 49). The maximum F/T is 0.47, whereas for a center landing it was 0.30. This maximum of 0.47 for Barricade No. 10 is larger than the value 0.40 for a 16-foot off-center landing with Barricade No. 9 (page 38).

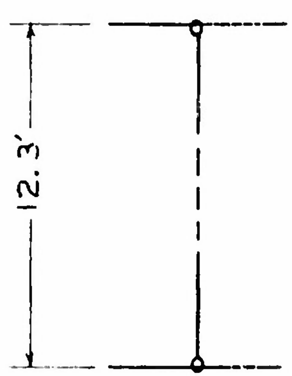
4. For a 16-foot off-center landing the angle ϕ is somewhat higher than for a center landing. The largest ϕ for a 16-foot off-center landing is 40° (page 49), whereas for a center landing it was 37° (page 47).

5. It is worth pointing out that although the component of force exerted perpendicular to the center line of the deck is fortunately directed toward the center line, unfortunately the reasonably large torque on the plane is in such a direction as to turn the plane away from the center line. With regard to both the magnitude and the direction of the torque exerted on the plane for a 16-foot off-center landing, Barricade No. 9 (page 38), is decidedly superior to Barricade No. 10.

6. As shown in the table on page 50, both the maximum F/T (0.57) and the maximum angle ϕ (44°) become less satisfactory for a 24-foot off-center landing. The torque for a 24-foot off-center landing is again relatively large and in the wrong direction, though not appreciably more objectionable than for a 16-foot off-center landing.

7. By comparing the series of photographs on page 46 with that on page 43, both for a 16-foot off-center landing, it is apparent that the behavior of Barricade No. 10 depends little upon whether it is attached to a doubly reeved or a singly reeved engine. The independence of the reeving is made all the more clear by comparing the data in the tables on pages 49 and 51, both for a 16-foot off-center landing, and by comparing the data in the tables on pages 50 and 52, both for a 24-foot off-center landing. The group has been told that the barricade in use (essentially No. 10) operates much more satisfactorily when attached to a singly reeved engine than when connected to a doubly reeved engine. The data presented here would not indicate that such should be the case. It is true that when the barricade is connected to a doubly reeved engine the rings at the ends of the vertical elements have to slide farther along the longitudinal elements than they do when a singly reeved engine is used. Presumably, however, the sliding is relatively free. If it is true that the barricade is much less satisfactory when connected to a doubly reeved arresting engine, the observation may indicate that sliding along the longitudinal elements is not as free as supposed. If the sliding is restricted the behavior of the barricade suffers also, though to a lesser extent, when connected to a singly reeved engine. Even when singly reeved there must be considerable sliding of the rings for the most effective operation.



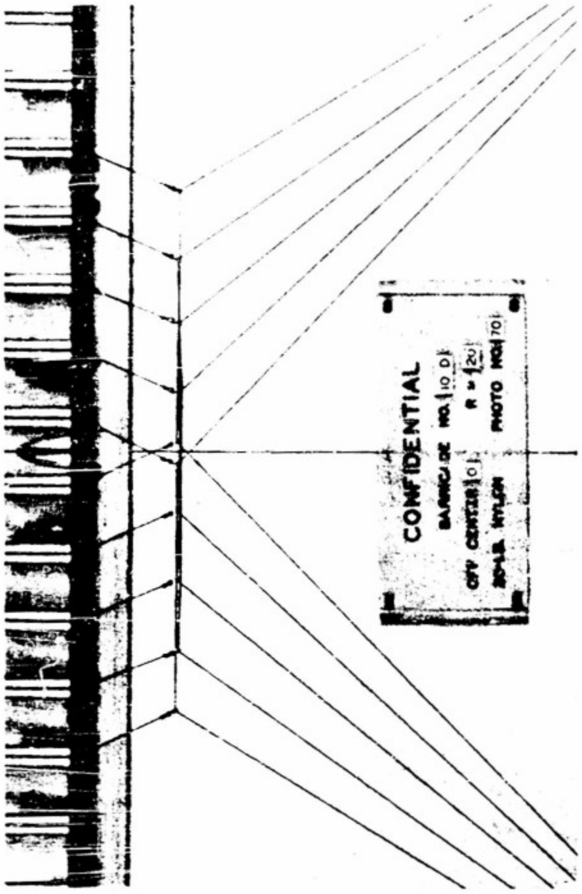


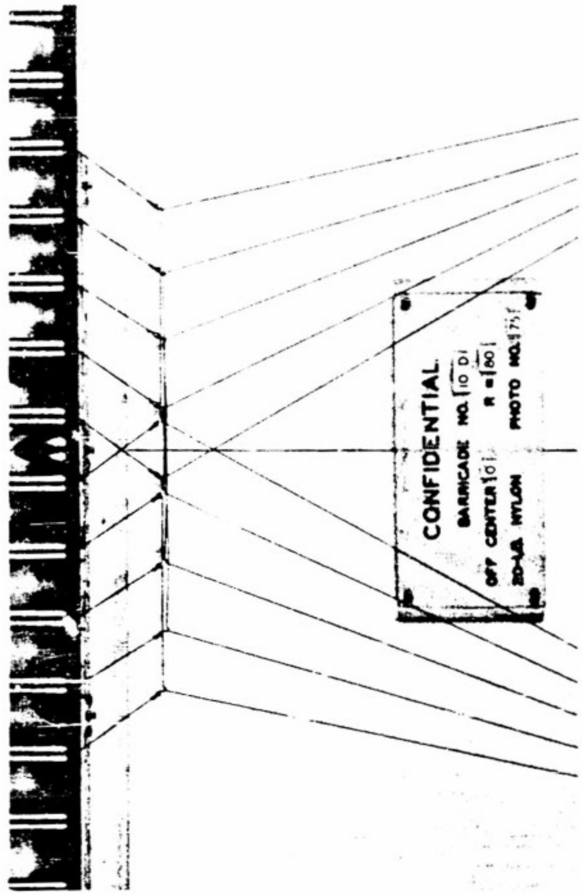
BARRICADE NO. 10 DESIGN

SCALE 3/16" = 1'

CONFIDENTIAL

E


CONFIDENTIAL
BARRICADE NO. 10 D1
OFF CENTER 0 R = 20
20-LB. NYLON PHOTO NO. 70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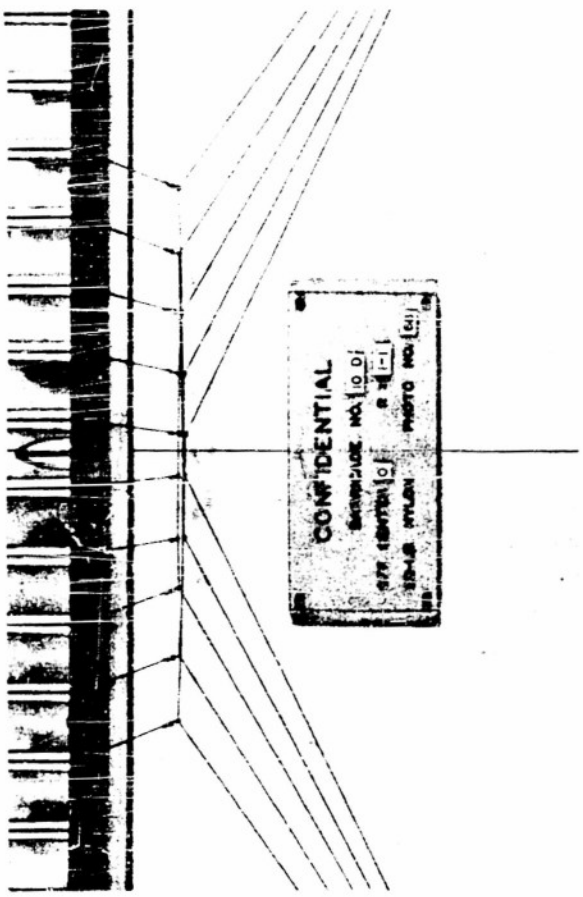
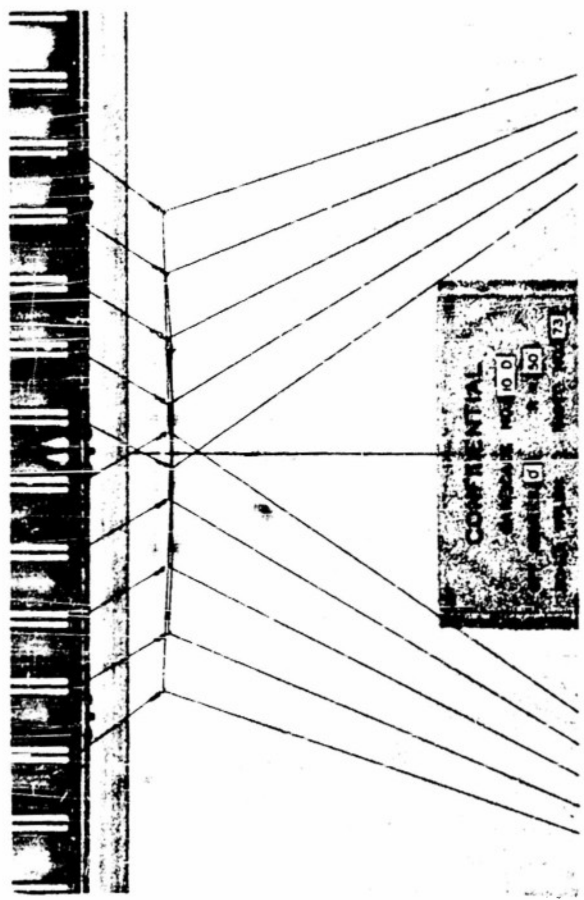
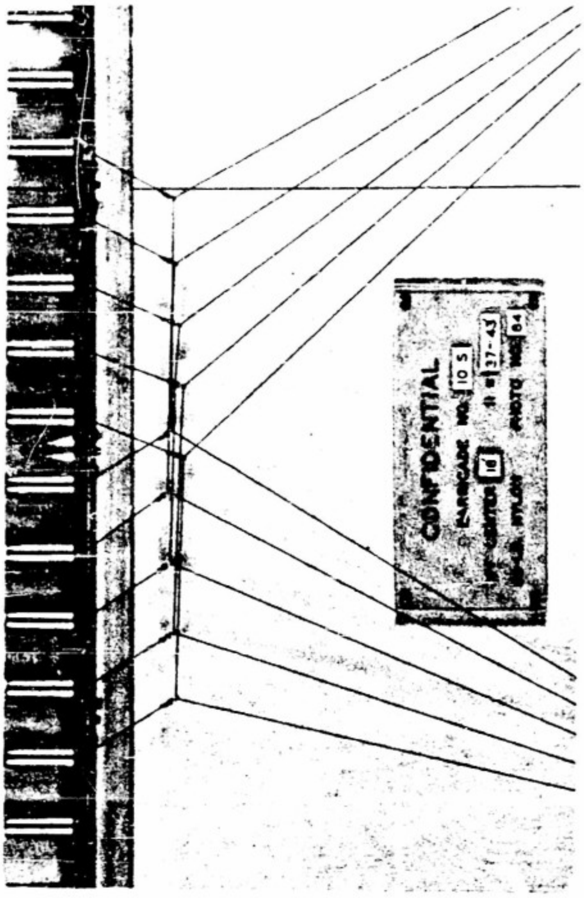
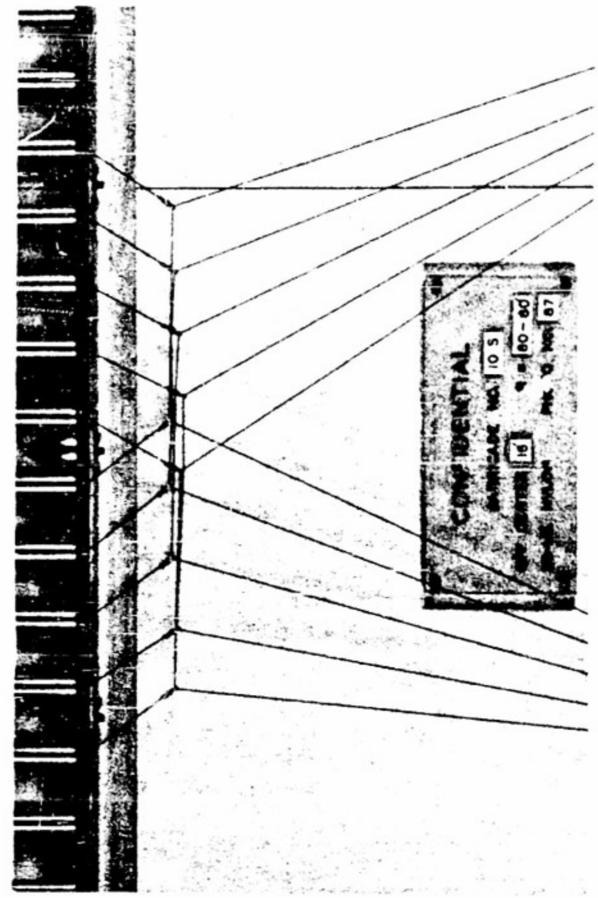
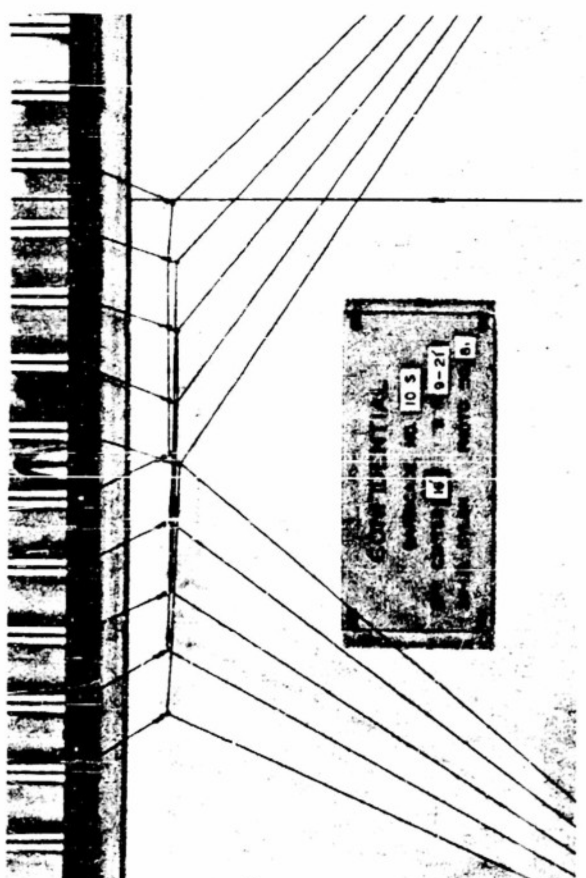
BARRICADE NO. 10 D1
OFF CENTER 0 R = 80
20-LB. NYLON PHOTO NO.

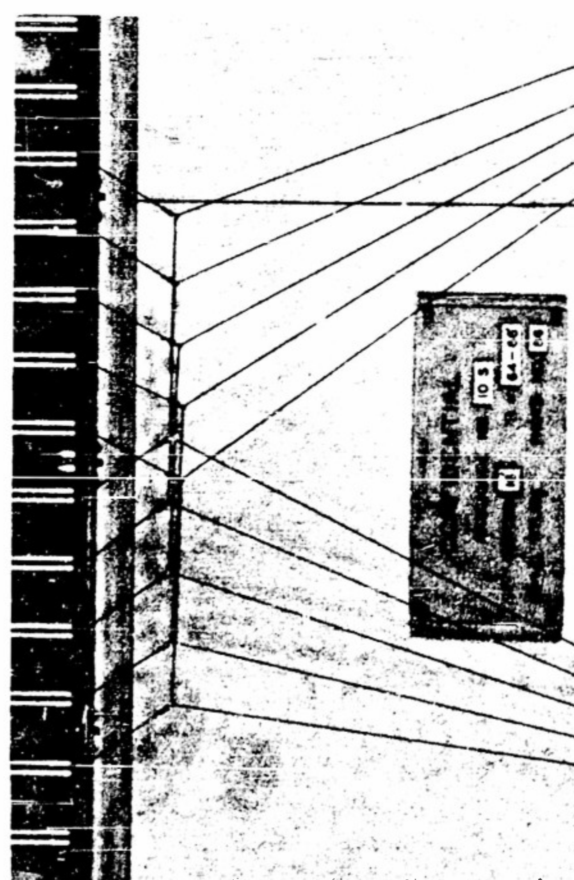

CONFIDENTIAL
NO. 10 D1
PHOTO NO.

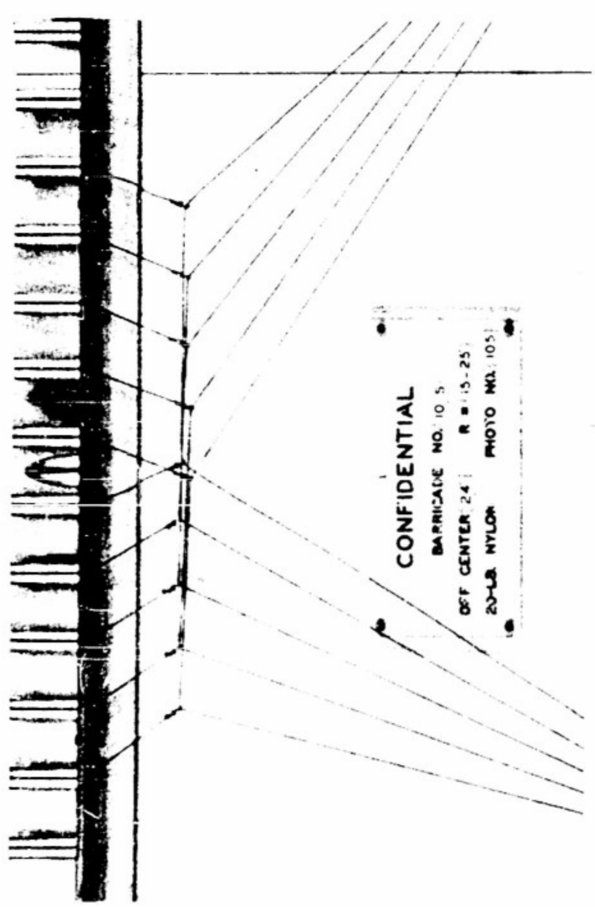

CONFIDENTIAL
10 D
50
73

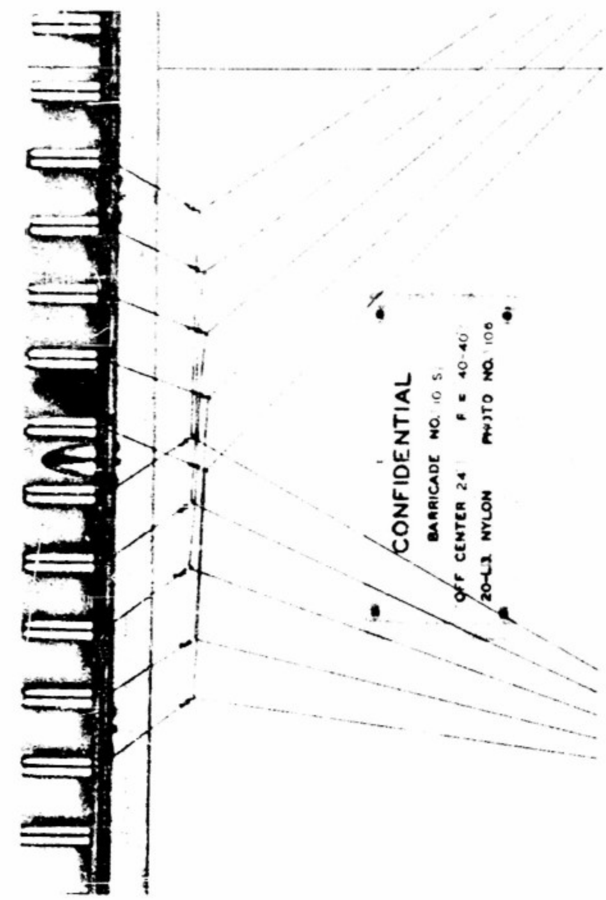

CONFIDENTIAL
10 S
16
37-43
84

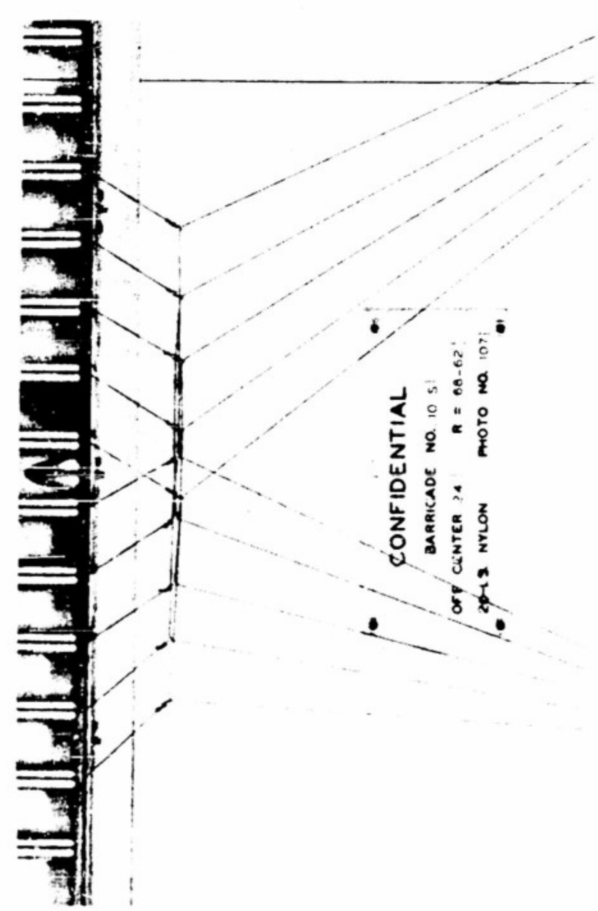

CONFIDENTIAL
10 S
16
80-86
87

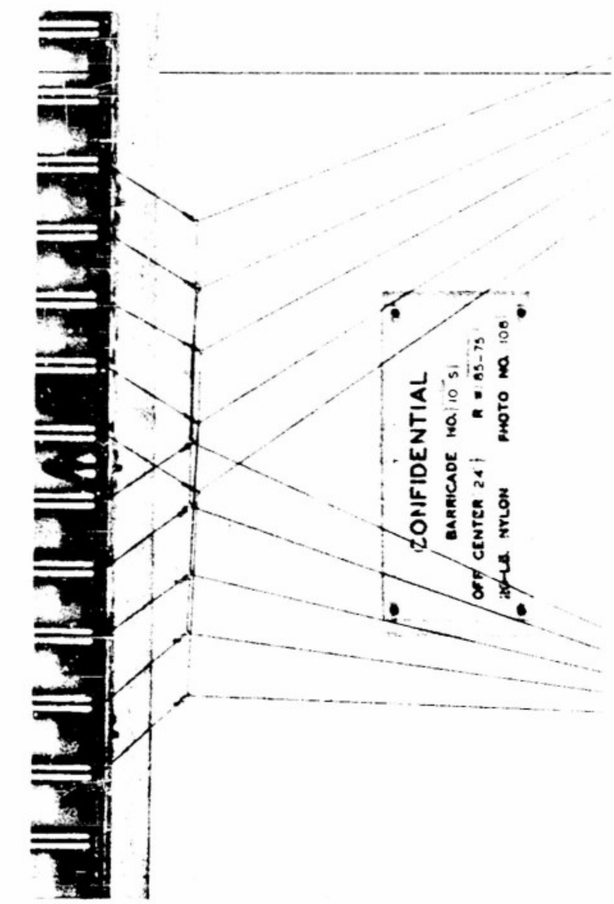

CONFIDENTIAL
10 S
0-21

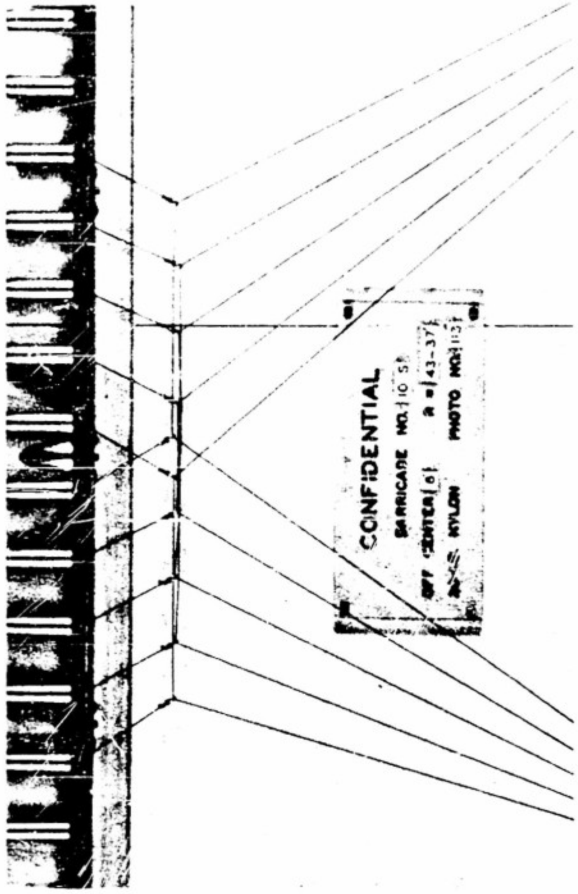

10 S
64-66
84

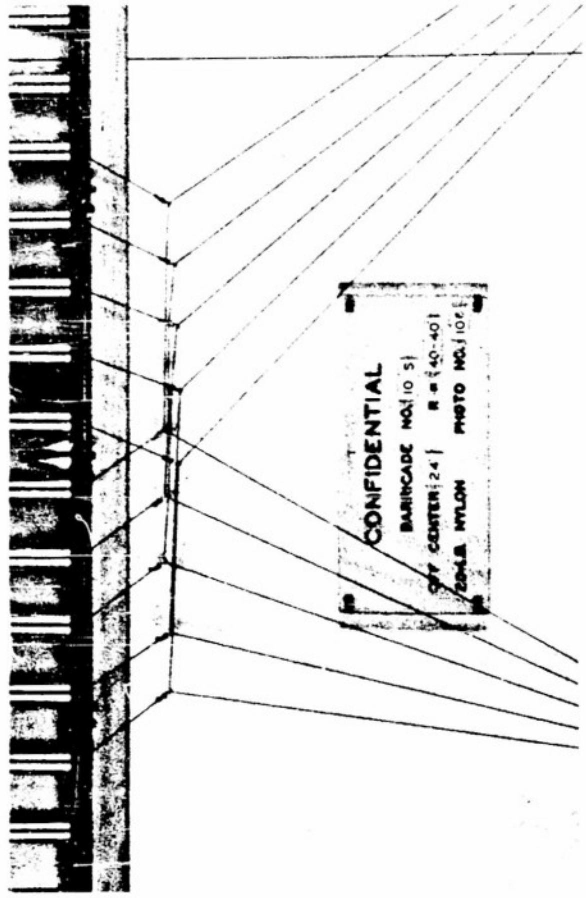

CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 24 R = 15-25
20-LB. NYLON PHOTO NO. 105

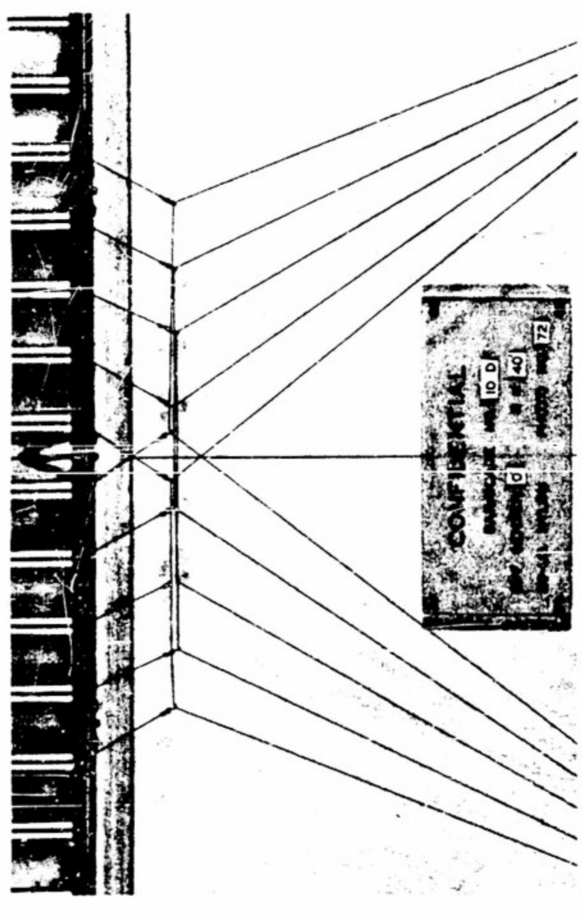

CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 24 R = 40-40
20-LB. NYLON PHOTO NO. 106

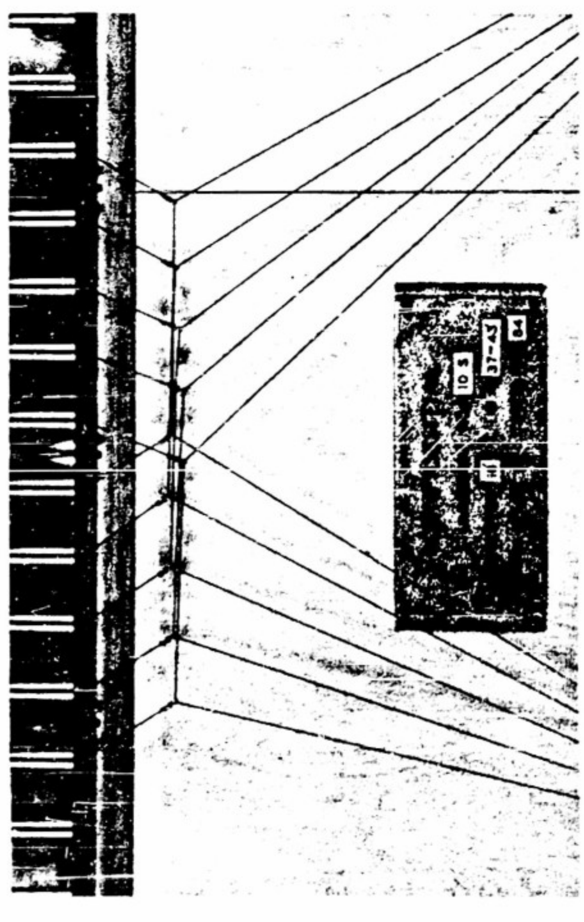

CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 24 R = 68-62
20-LB. NYLON PHOTO NO. 107

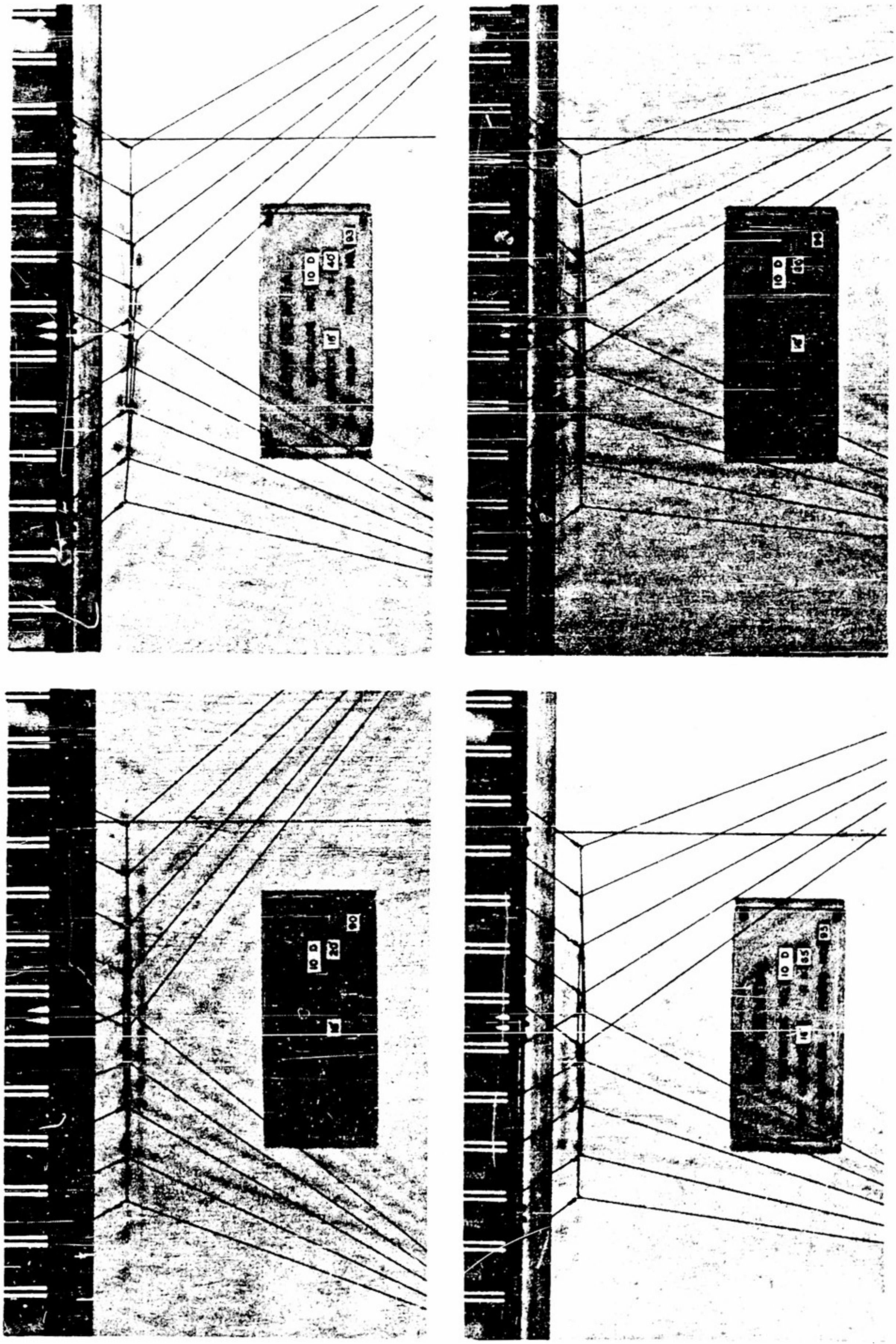

CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 24 R = 85-75
20-LB. NYLON PHOTO NO. 108


CONFIDENTIAL
BARRICADE NO. 10 S
OFF CENTER 6 R = 43-37
NYLON PHOTO NO. 113


CONFIDENTIAL
BARRICADE NO. 10 S
OFF CENTER 24 R = 40-40
NYLON PHOTO NO. 106


10 D
0
40
72


10 S
37-43
84



Barricade No. 10 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1	10	20	30	40	50	65	80
Photo No.	68	69	70	71	72	73	74	75
F_1/T	.10	.16	.19	.23	.25	.26	.27	.29
F_2/T	.11	.14	.17	.18	.21	.20	.23	.24
F_3/T	.08	.12	.12	.13	.14	.14	.16	.15
F_4/T	.09	.12	.14	.15	.17	.18	.19	.19
F_5/T	.08	.13	.14	.18	.20	.20	.22	.23
F_6/T	.07	.11	.14	.15	.18	.18	.19	.20
F_7/T	.09	.12	.13	.15	.16	.17	.19	.19
F_8/T	.08	.13	.12	.13	.14	.14	.16	.15
F_9/T	.11	.14	.17	.18	.21	.21	.23	.24
F_{10}/T	.12	.18	.22	.26	.28	.27	.29	.30
Max. ø	22°	25°	26°	27°	34°	37°	37°	36°
Element	#1	#1	#1	#1	#5	#1	#1	#1

Maximum F/T at any runout = 0.30

Maximum angle ø at any runout = 37°

F_c/T at 40-foot runout = 0

F_c/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 10 S

Plane Wings Straight

Singly Reeved
8-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	43-37
Photo No.	113
F_1/T	.25
F_2/T	.24
F_3/T	.17
F_4/T	.17
F_5/T	.17
F_6/T	.16
F_7/T	.17
F_8/T	.15
F_9/T	.19
F_{10}/T	.20
Max. ϕ	35°
Element	#1

Maximum F/T at 40-foot runout = 0.25

Maximum angle ϕ at 40-foot runout = 35°

F_c/T at 40-foot runout = 0.12

Torque/T at 40-foot runout = 0.9 ft.

Barricade No. 10 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1-17	9-21	17-27	26-34	37-43	48-52	64-66	80-80
Photo No.	80	81	82	83	84	85	86	87
F_1/T	.41	.43	.46	.47	.47	.46	.45	.45
F_2/T	.30	.31	.32	.34	.32	.32	.31	.32
F_3/T	.17	.17	.14	.16	.16	.16	.19	.20
F_4/T	.07	.08	.09	.11	.12	.13	.16	.18
F_5/T	0	.01	.02	.04	.06	.09	.12	.14
F_6/T	.17	.20	.22	.24	.24	.25	.26	.27
F_7/T	.13	.16	.18	.20	.20	.21	.22	.24
F_8/T	.10	.12	.11	.12	.12	.13	.15	.16
F_9/T	.05	.07	.07	.09	.10	.12	.14	.16
F_{10}/T	0	.01	.02	.04	.06	.09	.13	.16
Max. ϕ	36°	34°	35°	35°	33°	37°	37°	40°
Element	#1	#1	#1	#1	#1	#4	#1	#4

Maximum F/T at any runout = 0.47

Maximum angle ϕ at any runout = 40°

F_o/T at 40-foot runout = 0.32

F_o/T at 80-foot runout = 0.70

Torque/T at 40-foot runout = -7.3 ft.

Torque/T at 80-foot runout = -5.4 ft.

Barricade No. 10 S

Plane Wings Straight

Singly Reeved
24-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	15-25	40-40	68-62	85-75
Photo No.	105	106	107	108
F_1/T	.57	.51	.50	.46
F_2/T	.35	.36	.37	.35
F_3/T	.17	.18	.22	.20
F_4/T	.06	.07	.13	.15
F_5/T	.00	.01	.10	.11
F_6/T	.22	.26	.32	.30
F_7/T	.17	.20	.22	.23
F_8/T	.09	.11	.16	.16
F_9/T	.04	.06	.10	.13
F_{10}/T	.00	.01	.09	.11
Max. ϕ	38°	38°	44°	44°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.57

Maximum angle ϕ at any runout = 44°

F_o/T at 40-foot runout = 0.42

F_o/T at 80-foot runout = 0.34

Torque/T at 40-foot runout = -8.6 ft.

Torque/T at 80-foot runout = -5.1 ft.

Barricade No. 10 D

Plane Wings Straight

Doubly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1	10	20	30	40	50	65	80
Photo No.	88	89	90	91	93	94	95	96
F_1/T	.27	.42	.50	.50	.50	.46	.45	.45
F_2/T	.23	.28	.34	.35	.35	.33	.32	.32
F_3/T	.13	.15	.16	.17	.19	.19	.18	.19
F_4/T	.08	.09	.11	.13	.14	.15	.16	.17
F_5/T	.03	.02	.04	.06	.08	.10	.12	.14
F_6/T	.10	.16	.22	.25	.27	.26	.26	.26
F_7/T	.10	.15	.19	.21	.21	.22	.22	.22
F_8/T	.07	.08	.10	.12	.14	.14	.14	.14
F_9/T	.06	.06	.08	.10	.12	.14	.15	.16
F_{10}/T	.02	.02	.04	.06	.08	.10	.12	.14
Max. Ø	29°	28°	30°	32°	42°	35°	39°	38°
Element	#1	#1	#1	#1	#1	#1	#1	#1

Maximum F/T at any runout = 0.50

Maximum angle Ø at any runout = 42°

F_c/T at 40-foot runout = 0.41

F_c/T at 80-foot runout = 0.14

Torque/T at 40-foot runout = -6.3 ft.

Torque/T at 80-foot runout = -6.4 ft.

Barricade No. 10 D

Plane Wings Straight

Doubly Reeved
24-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	20	40	65	80
Photo No.	109	110	111	112
F_1/T	.50	.56	.50	.49
F_2/T	.32	.41	.39	.38
F_3/T	.13	.20	.23	.22
F_4/T	.02	.09	.13	.16
F_5/T	.00	.02	.08	.11
F_6/T	.20	.28	.29	.30
F_7/T	.15	.23	.27	.28
F_8/T	.07	.13	.15	.16
F_9/T	.01	.06	.11	.13
F_{10}/T	.00	.02	.08	.11
Max. ϕ	35°	39°	42°	44°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.56

Maximum angle ϕ at any runout = 44°

F_c/T at 40-foot runout = 0.50

F_c/T at 80-foot runout = 0.37

Torque/T at 40-foot runout = -9.2 ft.

Torque/T at 80-foot runout = -5.6 ft.

Barricade No. 11

Lengthening of successive vertical elements of Barricade No. 10 as one proceeds from the center toward either side, would result in a barricade improved in the following respects:

1. Even for a center landing the forces in the several vertical elements would be more nearly equal.

2. For an off-center landing the forces in those elements farthest from the center line of the deck would be reduced materially. This improvement would be highly desirable.

3. The torque exerted in an off-center landing would be reduced greatly, or even reversed in direction. This would also represent a desirable improvement.

Barricade No. 11 was designed with these improvements in mind. The structure of the barricade is shown on page 55. The only difference between this barricade and No. 10 is in the lengths of the vertical elements. Whereas in No. 10 all elements were of equal length, in No. 11 the length increases (except for those elements near center) as the distance from the center to the element becomes greater. The outermost element shown, which is necessary for a 24-foot off-center engagement, is 24 feet long in Barricade No. 11 whereas it was but 12 feet long in No. 10.

The series of photographs on pages 56, 57 and 58 illustrate respectively the behavior of Barricade No. 11 for a center landing, a 16-foot off-center landing and a 24-foot off-center landing, all with a singly reeved arresting engine. Data for these engagements, as well as for an 8-foot off-center landing, are shown in the tables on pages 60-63. Relative behavior at a runout of 40 feet for off-center landings of 0, 8, 16 and 24 feet is illustrated by the series of photographs on page 59. Although the corresponding photographs are not included in this report, the tabular data on page 64 show the behavior of this barricade for a 24-foot off-center landing when the barricade is connected to a doubly reeved engine.

For the purpose of comparing this barricade with No. 10, the following comments are offered. Numerical values are taken from the tables on the pages indicated. These values have been arranged in tabular form for a later comparison, and appear on page 78.

1. For a center landing there has been some reduction in the maximum F/T. The maximum is 0.26 for No. 11 (page 60), as compared to 0.30 for No. 10 (page 47).

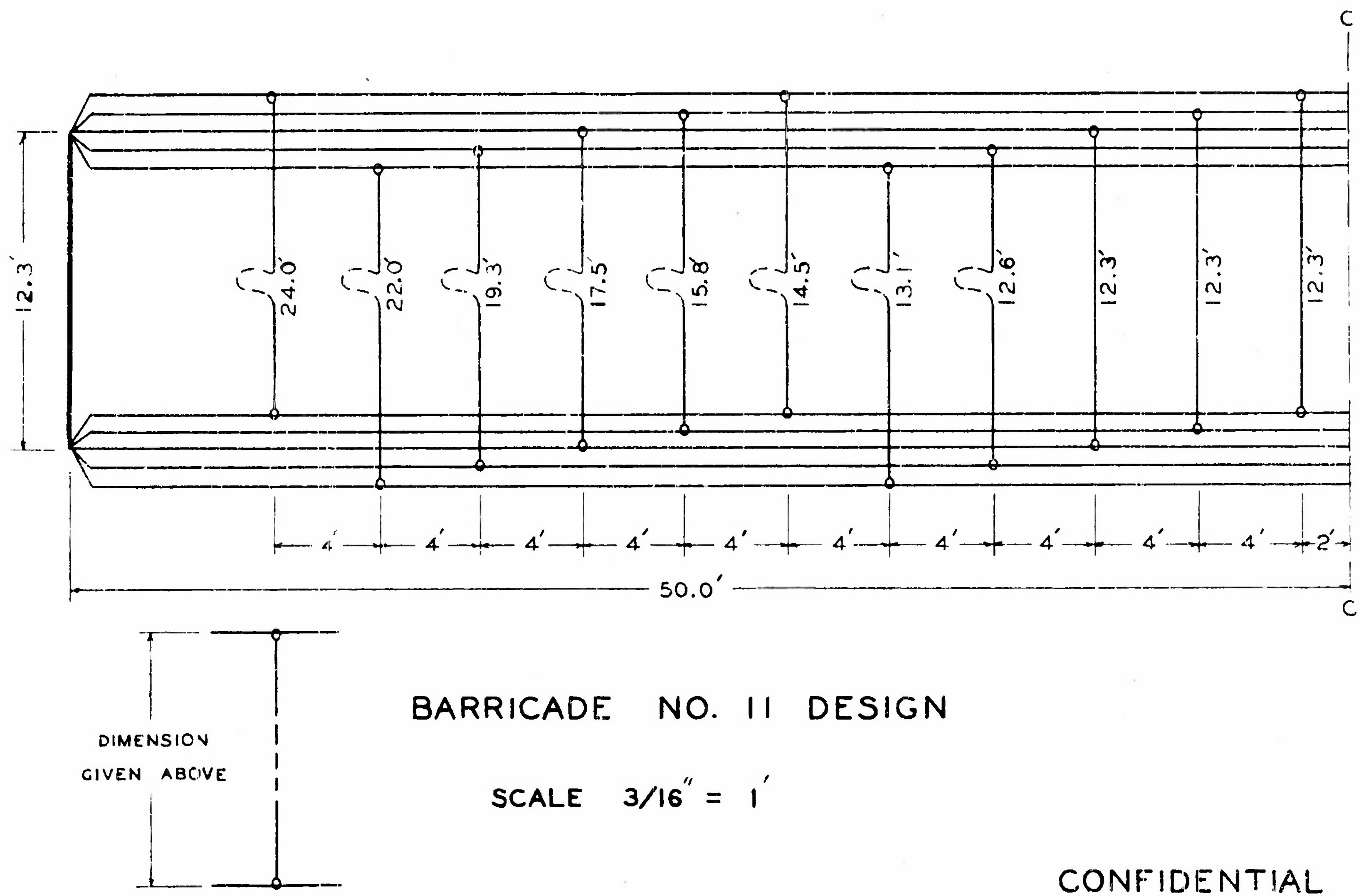
2. For a 16-foot off-center landing the maximum F/T of 0.27 for No. 11 (page 62) represents a decided reduction from the value 0.47 for No. 10 (page 49). Furthermore, No. 11 produces a much more favorable torque, both as to magnitude and direction. Whereas for a runout of 40 feet No. 10 exerts a torque/T of -7.3 ft. (page 49), No. 11 exerts a torque/T of 0.5 ft. (page 62).

3. Similar improvement is noted for a 24-foot off-center engagement. The maximum F/T for Barricade No. 11 is 0.31 (page 63), whereas it was 0.57 for No. 10 (page 50). Likewise, for a runout of 40 feet, the torque/T is 1.5 ft. for No. 11 whereas it was -8.6 ft. for No. 10.

4. As against these improvements, Barricade No. 11 is inferior to No. 10 in only one respect. For 16 and 24-foot off-center engagements the maximum angle ϕ is slightly larger for No. 11. It is 33° as against 37° for a center landing, 44° as against 40° for a 16-foot off-center landing, and 47° as against 44° for a 24-foot off-center landing.

5. As was true for Barricade No. 10, it apparently makes little difference whether No. 11 is attached to a singly reeved or a doubly reeved arresting engine. This is shown by comparison of the tables on pages 63 and 64.

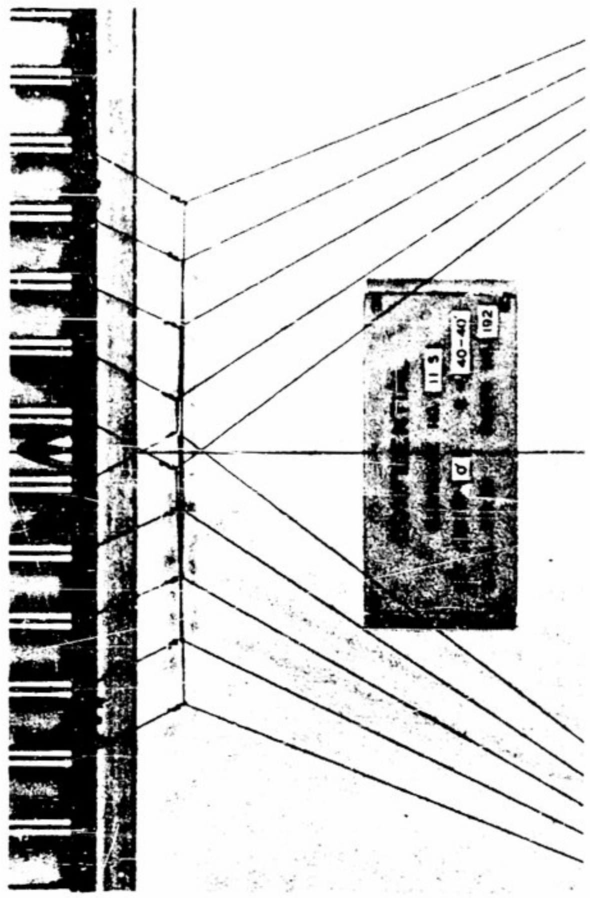
Barricade Nos. 12, 13, 14, and 15 (as well as later Nos. 20, 21, 22 and 23) are concerned with planes having sweptback wings. Some of them will be discussed later.

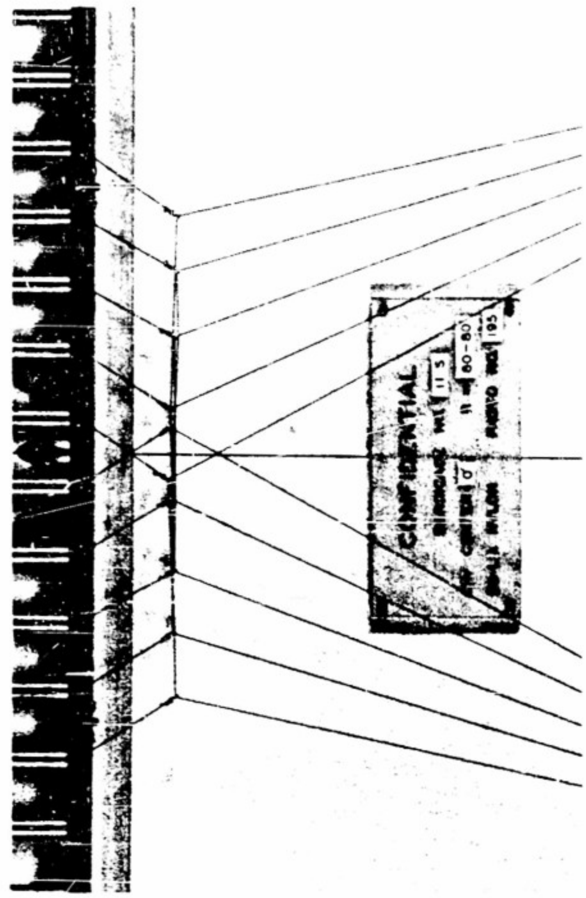


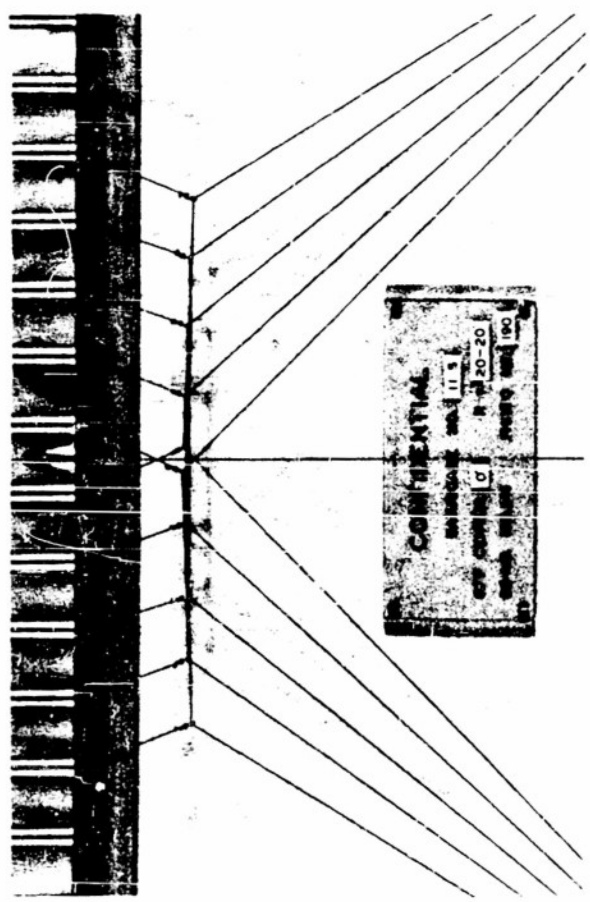
BARRICADE NO. 11 DESIGN

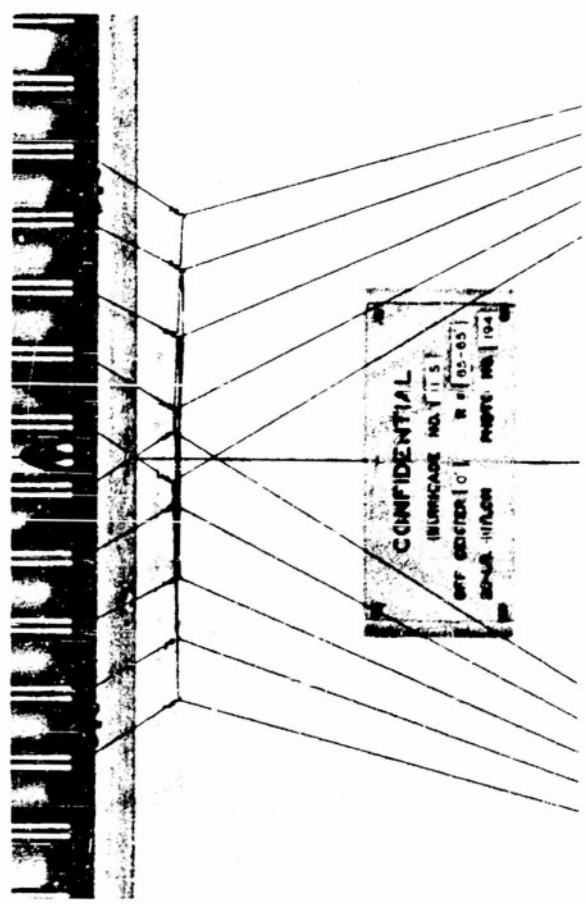
SCALE 3/16" = 1'

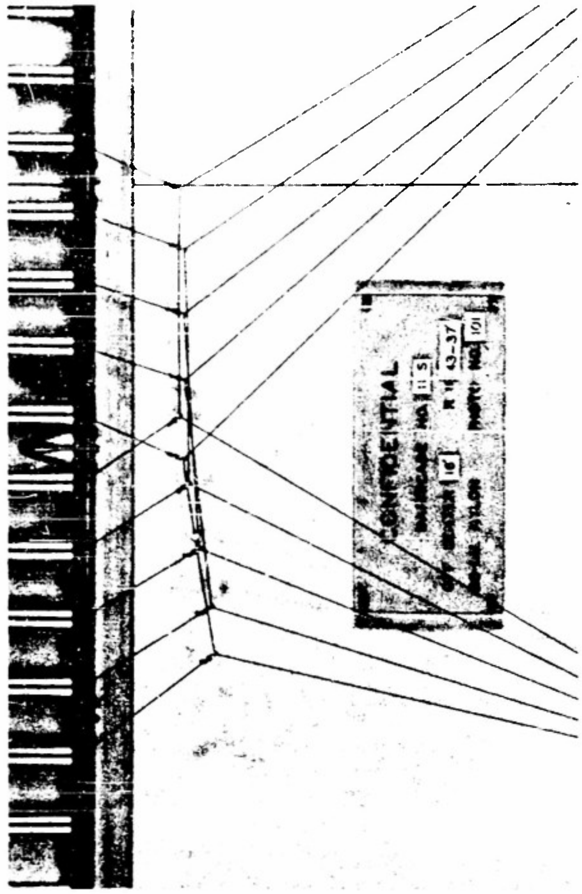
CONFIDENTIAL

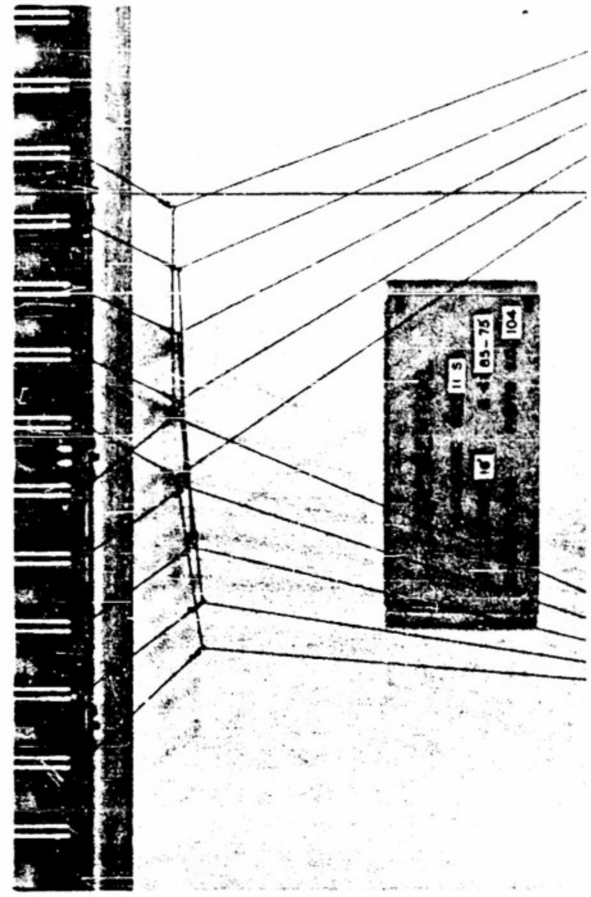

11 S
40-40
192

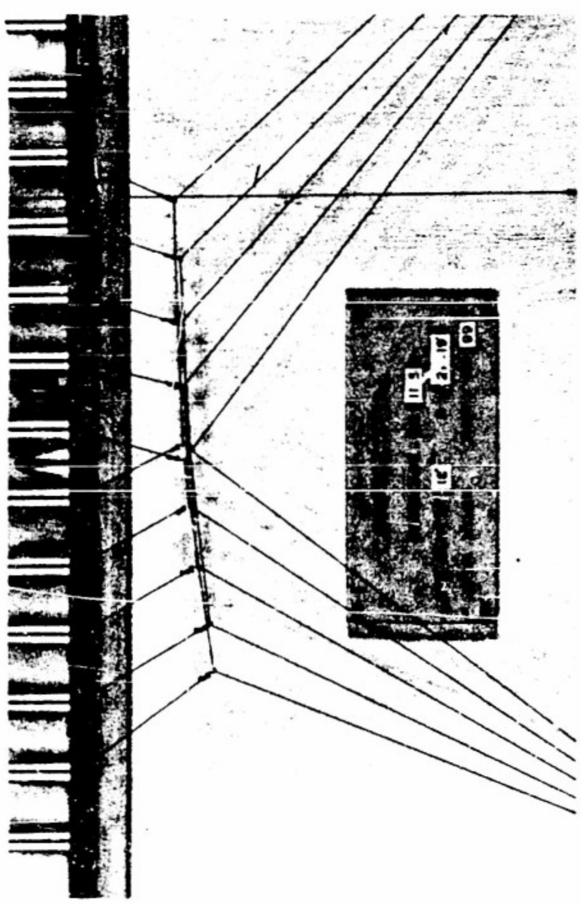

CONFIDENTIAL
11 S
80-80
195

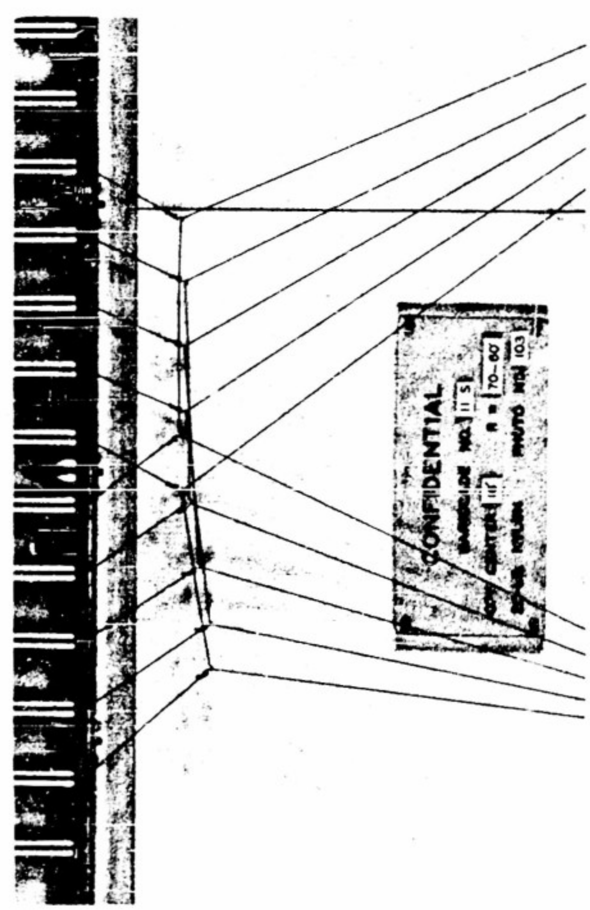

CONFIDENTIAL
11 S
20-20
190

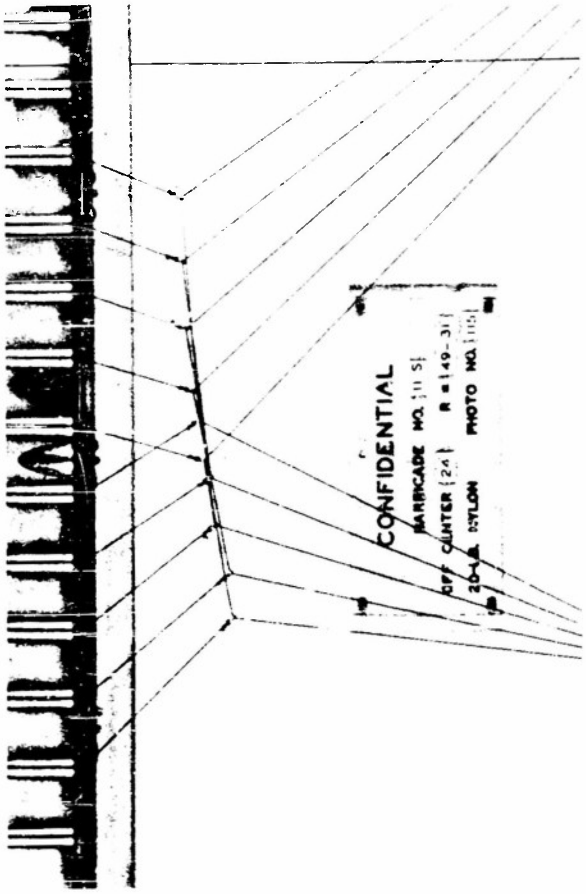

CONFIDENTIAL
11 S
85-85
194

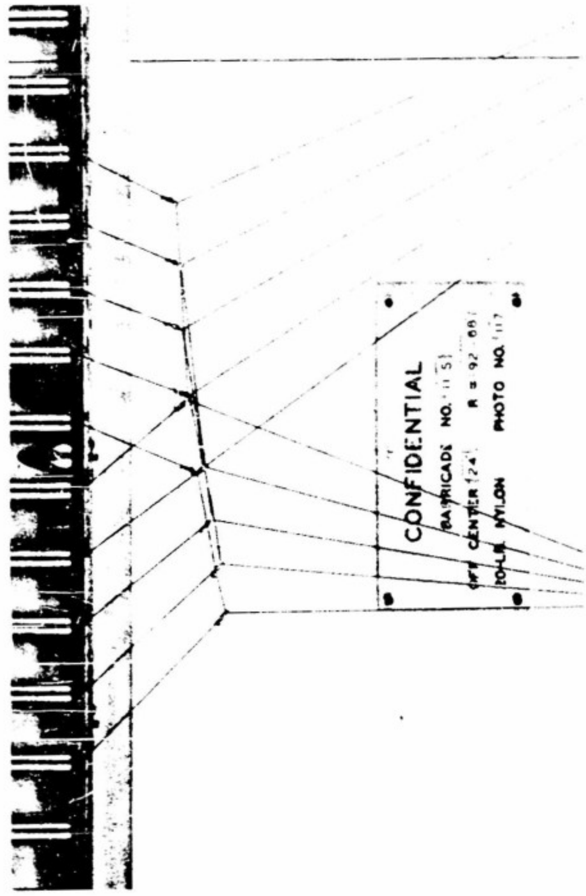

CONFIDENTIAL
11 S
43–37
101

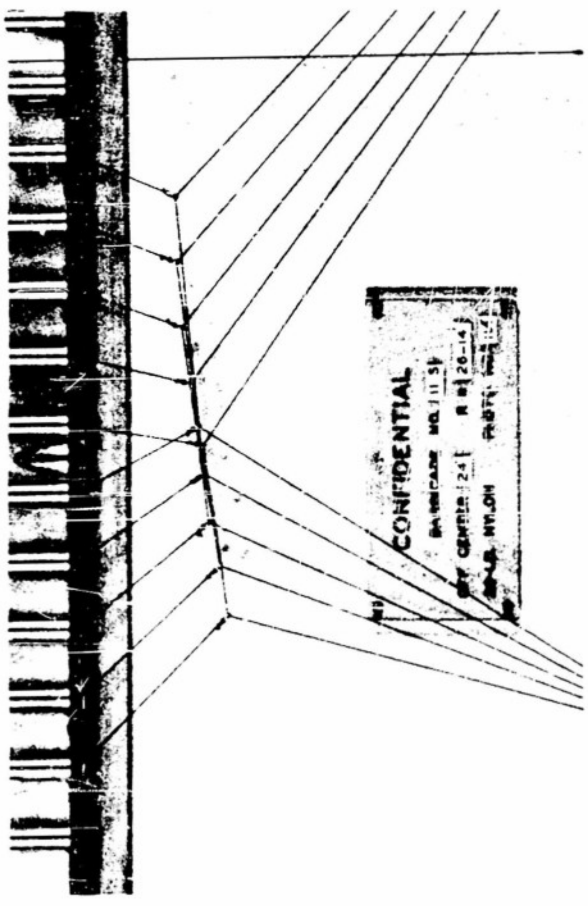

11 S
85–75
104


11 S


CONFIDENTIAL
11 S
70–80
103


CONFIDENTIAL
BARRICADE NO. (11 5)
OFF CENTER (24) R = (49-31)
20-LB. NYLON PHOTO NO. (115)


CONFIDENTIAL
BARRICADE NO. (11 5)
OFF CENTER (24) R = (92-68)
20-LB. NYLON PHOTO NO. (117)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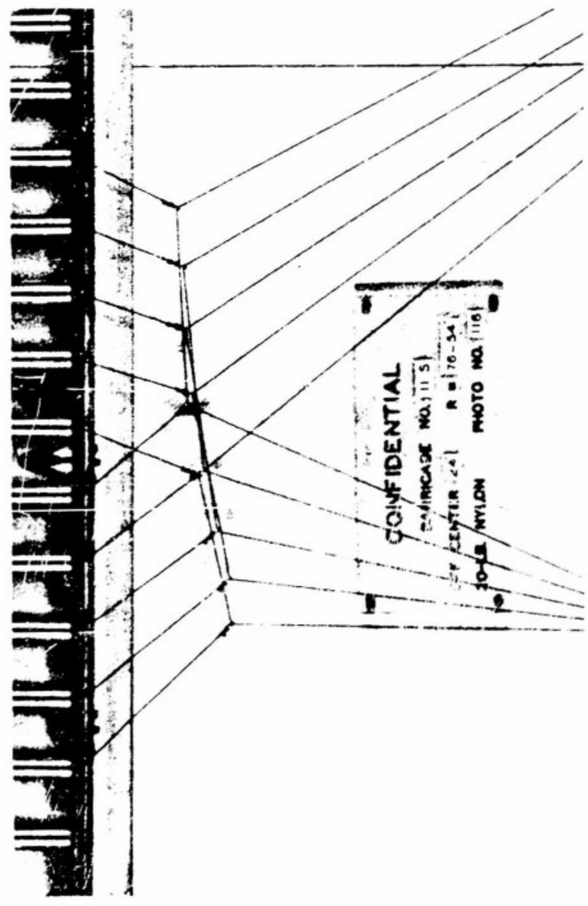
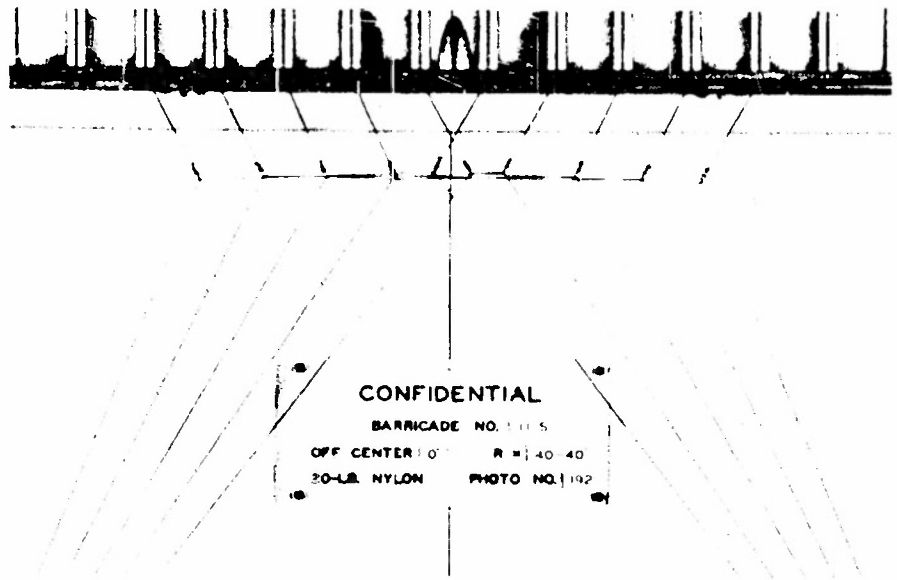
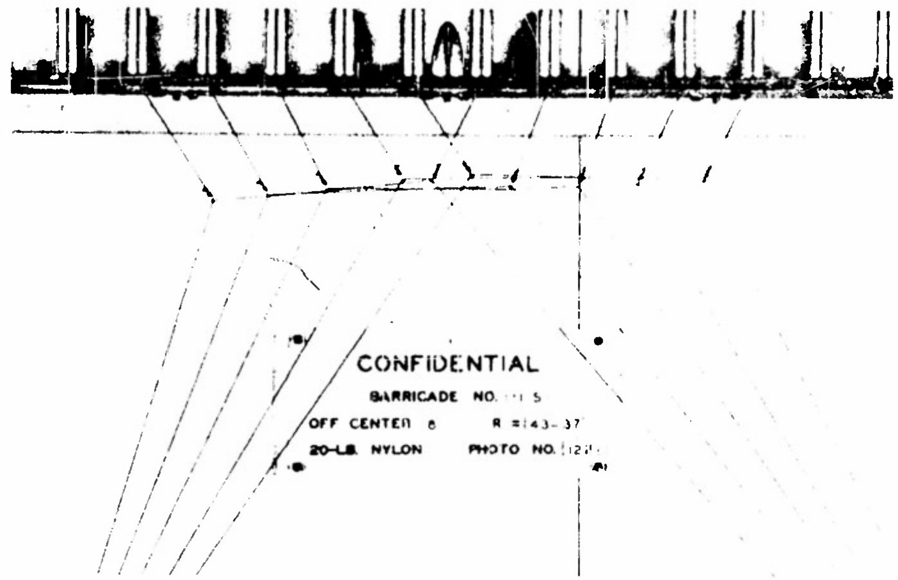
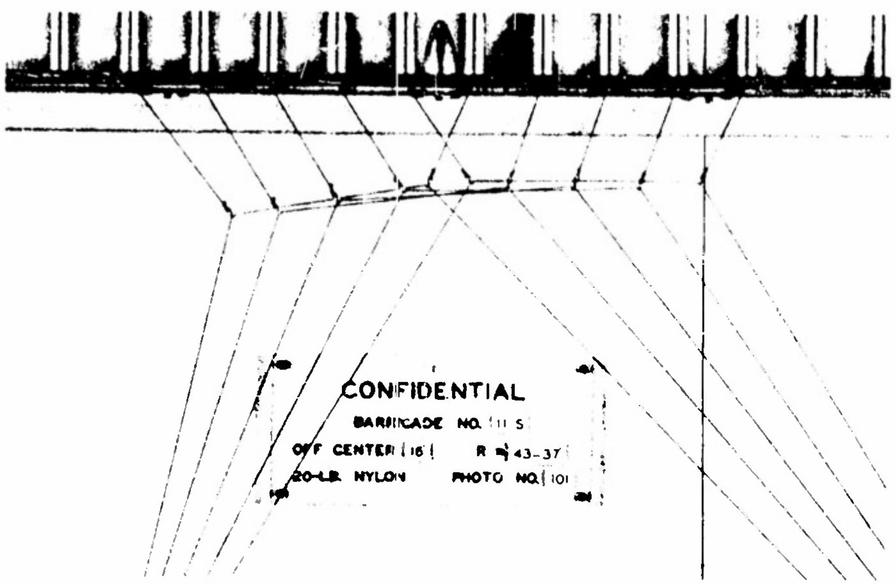
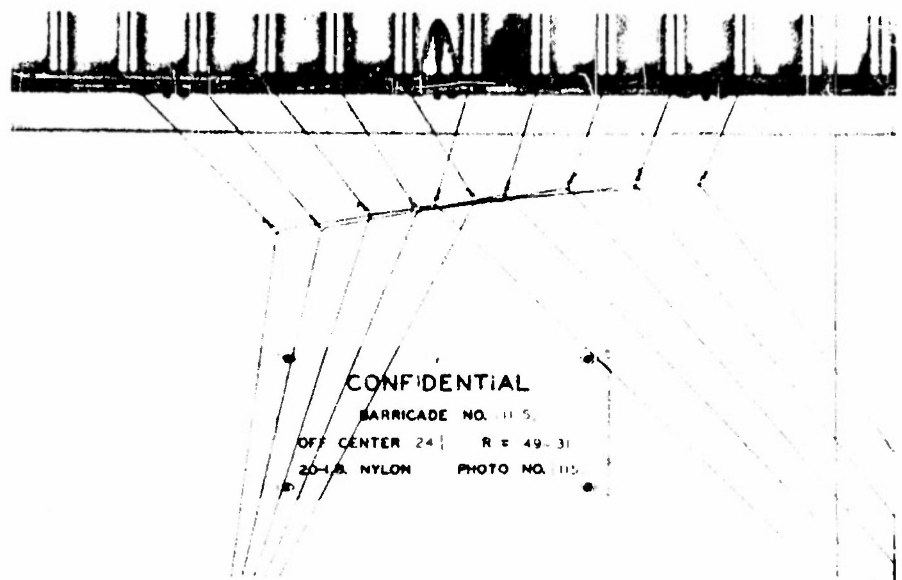
BARRICADE NO. (11 5)
OFF CENTER (24) R = (26-14)
20-LB. NYLON


CONFIDENTIAL
BARRICADE NO. (11 5)
CENTER (24) R = (76-54)
20-LB. NYLON PHOTO NO. (116)


CONFIDENTIAL
BARRICADE NO. 11 5
OFF CENTER 0'
R = 40-40
20-LB. NYLON
PHOTO NO. 192


CONFIDENTIAL
BARRICADE NO. 11 5
OFF CENTER 8
R = 43-37
20-LB. NYLON
PHOTO NO.


CONFIDENTIAL
BARRICADE NO. 11 5
OFF CENTER 16'
R = 43-37
20-LB. NYLON
PHOTO NO. 101


CONFIDENTIAL
BARRICADE NO. 11 5
OFF CENTER 24'
R = 49-31
20-LB. NYLON
PHOTO NO. 115

Barricade No. 11 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1-1	10-10	20-20	30-30	40-40	50-50	65-65	80-80
Photo No.	188	189	190	191	192	193	194	195
F_1/T	.11	.17	.19	.20	.21	.24	.26	.26
F_2/T	.12	.15	.18	.19	.19	.20	.23	.24
F_3/T	.12	.14	.16	.17	.17	.17	.21	.21
F_4/T	.11	.13	.15	.15	.15	.17	.19	.19
F_5/T	.09	.13	.15	.16	.16	.18	.19	.21
F_6/T	.09	.13	.15	.16	.16	.18	.19	.21
F_7/T	.11	.13	.15	.15	.16	.18	.20	.19
F_8/T	.12	.14	.16	.17	.17	.18	.20	.21
F_9/T	.12	.16	.17	.19	.18	.21	.24	.25
F_{10}/T	.12	.18	.20	.20	.22	.25	.26	.26
Max. ϕ	14°	23°	25°	28°	29°	32°	32°	33°
Element	#1	#5	#5	#5	#5	#5	#5	#5

Maximum F/T at any runout = 0.26

Maximum angle ϕ at any runout = 33°

F_c/T at 40-foot runout = 0

F_c/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 11 S

Plane Wings Straight

Singly Reeved
8-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	43-37
Photo No.	122
F_1/T	.21
F_2/T	.20
F_3/T	.17
F_4/T	.19
F_5/T	.20
F_6/T	.14
F_7/T	.15
F_8/T	.15
F_9/T	.19
F_{10}/T	.23
Max. ϕ	33°
Element	#1

Maximum F/T at 40-foot runout = 0.23

Maximum angle ϕ at 40-foot runout = 33°

F_s/T at 40-foot runout = 0.14

Torque/T at 40-foot runout = 0.4 ft.

Barricade No. 11 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1-5	10-10	21-19	32-28	43-37	54-46	70-60	85-75
Photo No.	97	98	99	100	101	102	103	104
F_1/T	.11	.18	.21	.20	.19	.19	.19	.18
F_2/T	.14	.18	.21	.20	.19	.20	.22	.22
F_3/T	.14	.17	.19	.18	.19	.20	.21	.22
F_4/T	.13	.16	.18	.18	.19	.21	.23	.25
F_5/T	.11	.13	.16	.17	.18	.21	.24	.24
F_6/T	.08	.13	.14	.15	.14	.14	.14	.13
F_7/T	.10	.13	.15	.16	.15	.16	.17	.17
F_8/T	.12	.13	.14	.15	.15	.17	.18	.18
F_9/T	.11	.13	.15	.18	.18	.21	.24	.25
F_{10}/T	.10	.12	.14	.17	.19	.23	.26	.27
Max. ∅	34°	30°	36°	37°	38°	40°	42°	44°
Element	#1	#1	#1	#1	#1	#1	#1	#1

Maximum F/T at any runout = 0.27

Maximum angle ∅ at any runout = 44°

F_o/T at 40-foot runout = 0.23

F_o/T at 80-foot runout = 0.23

Torque/T at 40-foot runout = 0.5 ft.

Torque/T at 80-foot runout = 2.5 ft.

Barricade No. 11 S

Plane Wings Straight

Singly Reeved
24-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	26-14	49-31	76-54	92-68
Photo No.	114	115	116	117
F_1/T	.21	.21	.16	.16
F_2/T	.20	.20	.20	.24
F_3/T	.18	.19	.22	.25
F_4/T	.16	.19	.24	.28
F_5/T	.13	.17	.24	.28
F_6/T	.14	.14	.12	.11
F_7/T	.15	.16	.18	.17
F_8/T	.14	.17	.20	.22
F_9/T	.14	.18	.25	.27
F_{10}/T	.12	.19	.27	.31
Max. ø	46°	46°	45°	47°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.31

Maximum angle ø at any runout = 47°

F_o/T at 40-foot runout = 0.31

F_o/T at 80-foot runout = 0.36

Torque/T at 40-foot runout = 1.5 ft.

Torque/T at 80-foot runout = 4.5 ft.

Barricade No. 11 D

Plane Wings Straight

Doubly Reeved
24-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	20	40	65	80
Photo No.	118	119	120	121
F_1/T	.20	.20	.15	.13
F_2/T	.20	.21	.19	.19
F_3/T	.19	.21	.21	.22
F_4/T	.15	.21	.25	.26
F_5/T	.13	.20	.24	.26
F_6/T	.14	.14	.11	.10
F_7/T	.15	.16	.16	.17
F_8/T	.14	.18	.19	.20
F_9/T	.13	.19	.23	.27
F_{10}/T	.11	.19	.25	.30
Max. ϕ	40°	42°	46°	48°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.30

Maximum angle ϕ at any runout = 48°

F_c/T at 40-foot runout = 0.34

F_c/T at 80-foot runout = 0.23

Torque/T at 40-foot runout = 1.5 ft.

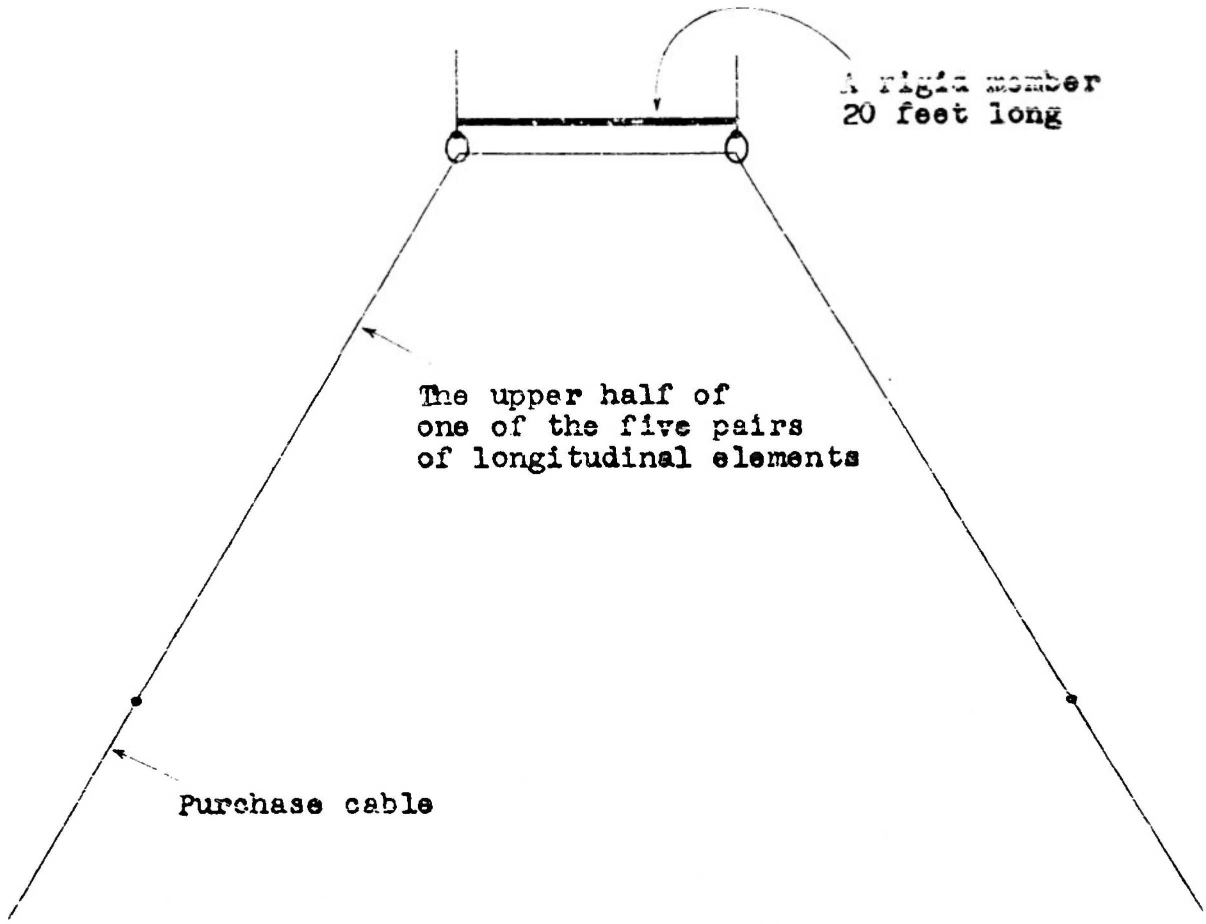
Torque/T at 80-foot runout = 4.7 ft.

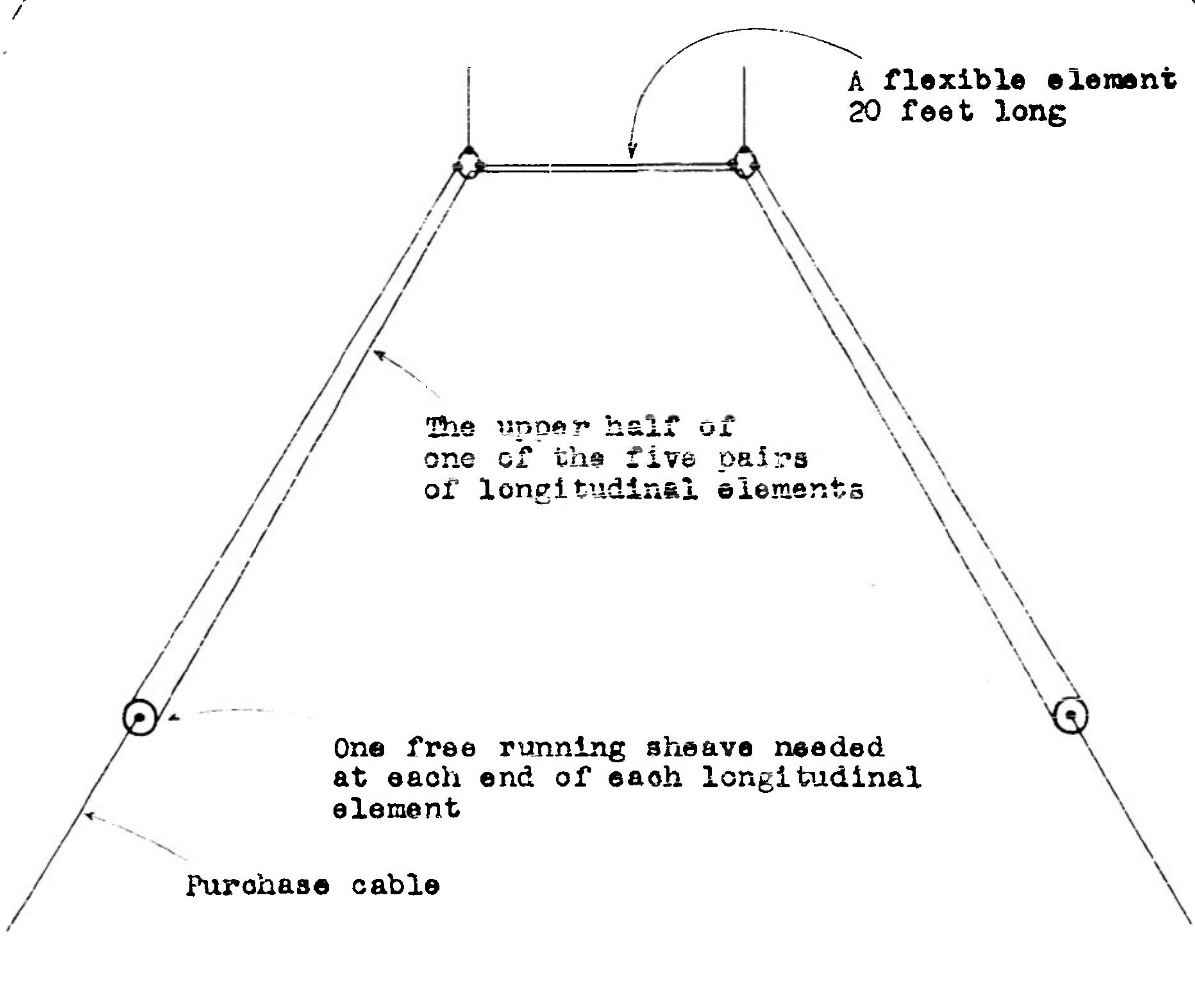
Barricade No. 16

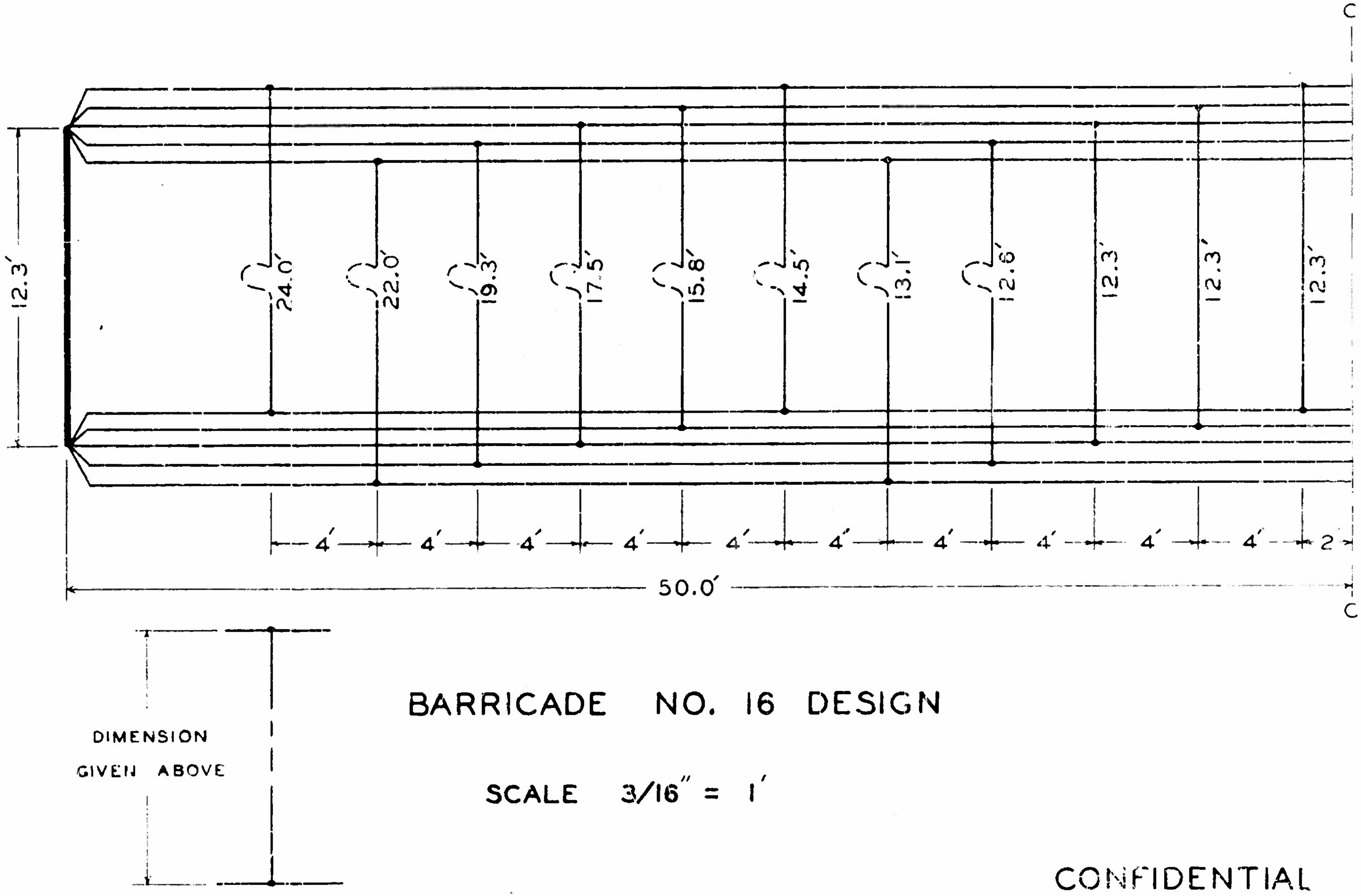
Barricade No. 16 represents a deliberate attempt to reduce the angle ϕ and still maintain the desirable features of No. 11. The large angles ϕ observed with Barricade Nos. 10 and 11 result primarily from the fact that the rings at the ends of the vertical elements are free to slide along the longitudinal elements. The angle would certainly be reduced by fastening the ends of the vertical elements in fixed positions. It would be well to know whether this change would render more unfavorable other characteristics of the barricade.

Barricade No. 16 was therefore constructed exactly like No. 11, except that the ends of the vertical elements were fixed in position. The design is shown on page 67. The behavior of the barricade for a center landing is shown by the series of photographs on page 68 and the tabular data on page 69. The behavior is entirely unsatisfactory even for a center landing.

In principle there are probably two ways of accomplishing the desired reduction in angle ϕ without sacrificing other desirable characteristics. Unfortunately, neither appears practical. The rings at the ends of the vertical elements must be allowed to slide along the longitudinal elements. Still, it is desirable to hold a fixed distance apart the ends of that pair of vertical elements which slide on a given pair of longitudinal elements. The two sketches on page 66 illustrate two methods by which this can be accomplished. The rigid member needed in the first sketch would be untenable. The sheaves needed in the second sketch would likewise be impractical. Too much friction would almost certainly result from an attempt to replace the sheaves with rings through which the element can slide.


A rigid member
20 feet long
The upper half of
one of the five pairs
of longitudinal elements
Purchase cable

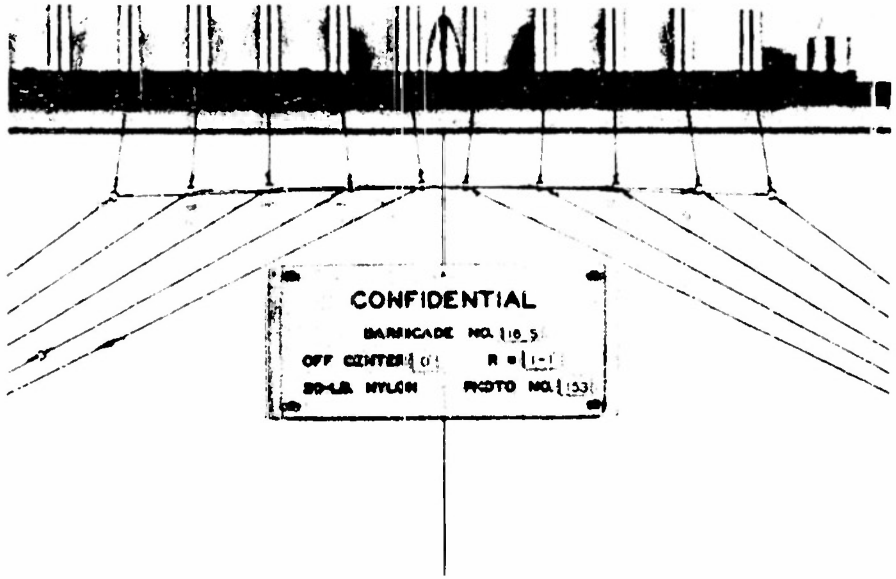

A flexible element
20 feet long
The upper half of
one of the five pairs
of longitudinal elements
One free running sheave needed
at each end of each longitudinal
element
Purchase cable

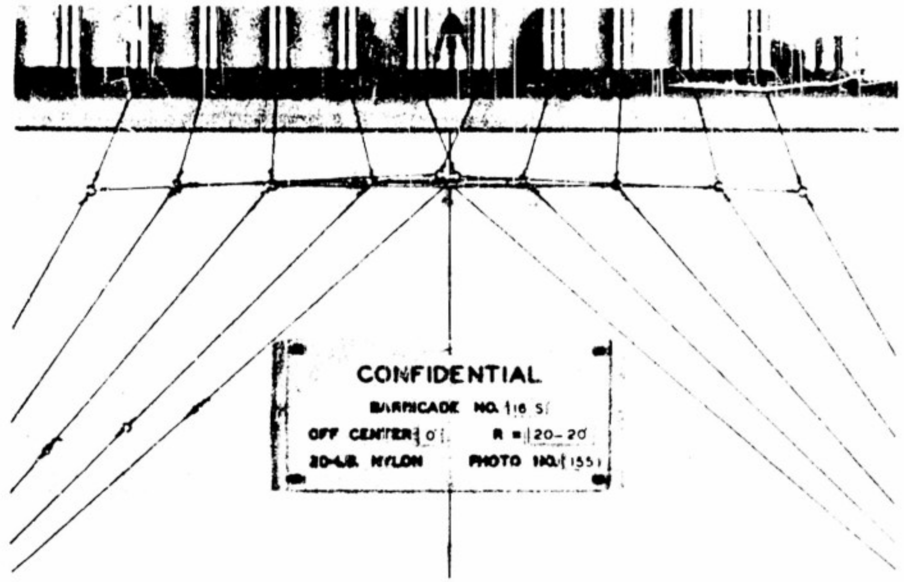


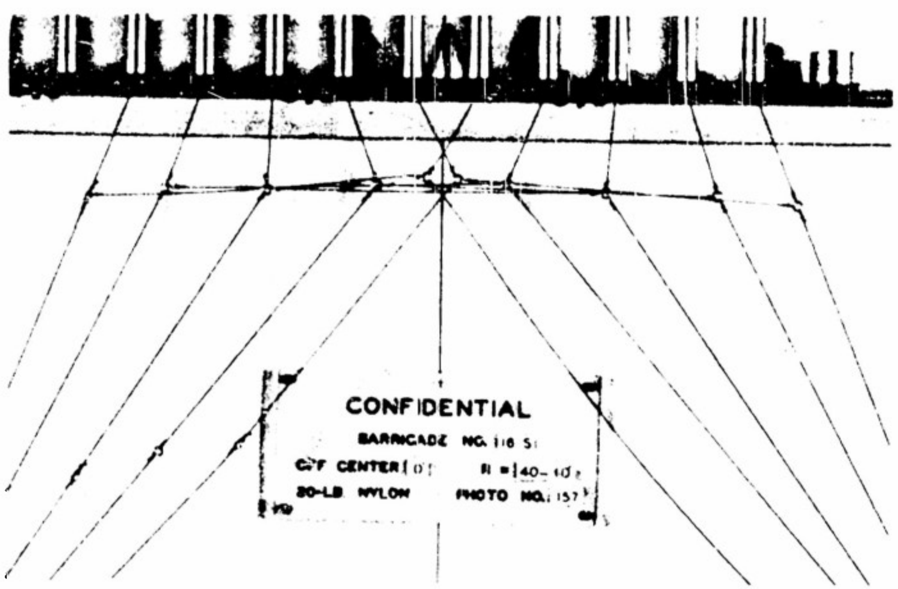
BARRICADE NO. 16 DESIGN

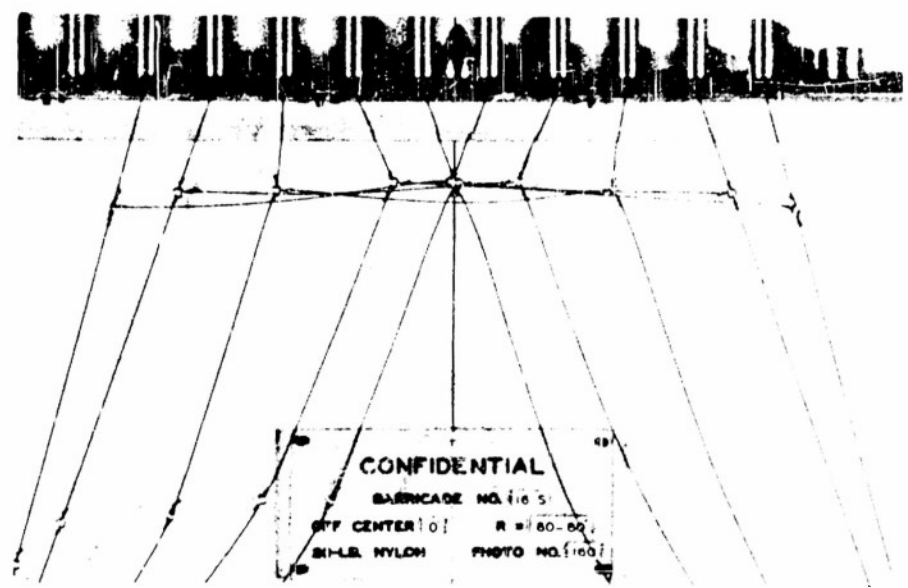
SCALE 3/16" = 1'

CONFIDENTIAL


CONFIDENTIAL
BARRICADE NO. 16 S
OFF CENTER 0 R = 1-1
20-LB. NYLON PHOTO NO. 153


CONFIDENTIAL
BARRICADE NO. 16 S
OFF CENTER 0 R = 20-20
20-LB. NYLON PHOTO NO. 155


CONFIDENTIAL
BARRICADE NO. 16 S
OFF CENTER 0 R = 40-40
20-LB. NYLON PHOTO NO. 157


CONFIDENTIAL
BARRICADE NO. 16 S
OFF CENTER 0 R = 60-60
20-LB. NYLON PHOTO NO. 160

Barricade No. 16 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1-1	10-10	20-20	30-30	40-40	50-50	65-65	80-80
Photo No.	153	154	155	156	157	158	159	160
F_1/T	.12	.30	.43	.50	.65	.73	.76	.78
F_2/T	.12	.17	.21	.20	.25	.28	.27	.26
F_3/T	.11	.10	.07	.04	.02	0	0	0
F_4/T	.10	.09	.06	.04	.03	.01	0	0
F_5/T	.08	.08	.04	.02	0	0	0	0
F_6/T	.08	.08	.05	.01	0	0	0	0
F_7/T	.10	.09	.06	.04	.03	.01	0	0
F_8/T	.11	.10	.07	.04	.02	0	0	0
F_9/T	.13	.18	.21	.21	.25	.28	.27	.26
F_{10}/T	.13	.29	.43	.50	.65	.73	.76	.78
Max. ϕ	8°	18°	23°	24°	22°	20°	21°	19°
Element	#1	#1	#1	#1	#1	#1	#2	#2

Maximum F/T at any runout = 0.78

Maximum angle ϕ at any runout = 25°

F_o/T at 40-foot runout = 0

F_o/T at 80-foot runout = 0

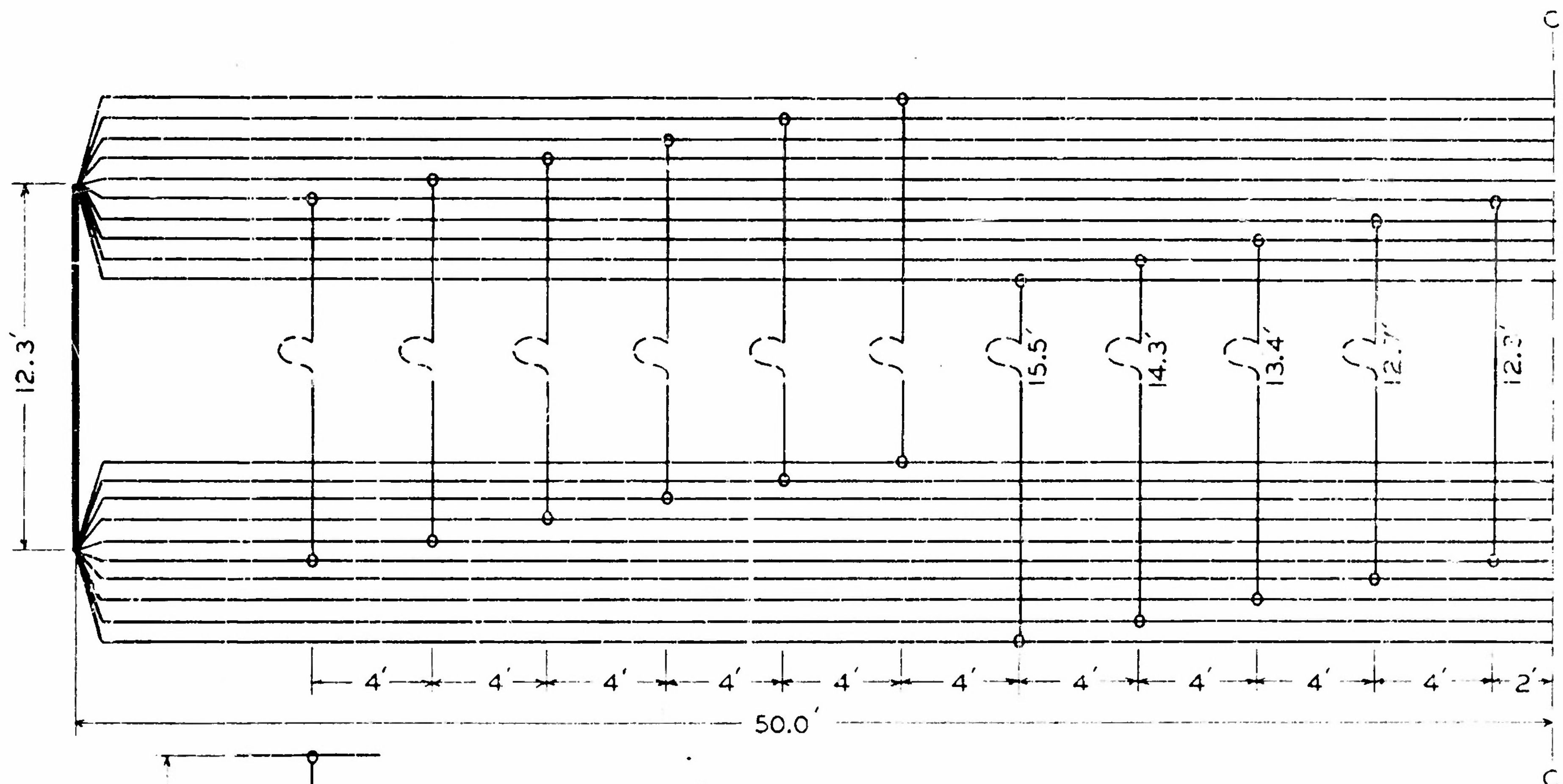
Torque/T at 40-foot runout = 0

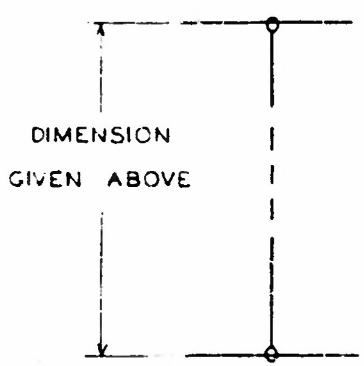
Torque/T at 80-foot runout = 0

Barricade No. 17

Barricade Nos. 17, 18 and 19 represent other attempts to reduce the angle ϕ and still retain other desirable characteristics. Nos. 17 and 18 represent preliminary designs, one proper for a center landing and the other proper for a 16-foot off-center landing. No. 19 represents a compromise which it was hoped would be good regardless of how far off center the landing might be. Each barricade utilizes 10 pairs of longitudinal elements. Each tenth vertical element is connected to a common pair of longitudinal elements.

Barricade No. 17 was designed to equalize the forces in the vertical elements for a center landing and a 40-foot runout, the equalization being accomplished by adjustment of the lengths of the elements. The design is shown on page 71. The behavior of the barricade is shown by the series of photographs on page 72 and by the tabular data on page 73. For a center landing the force distribution among the vertical elements is highly satisfactory, and the magnitude of the angle ϕ is reasonably satisfactory.

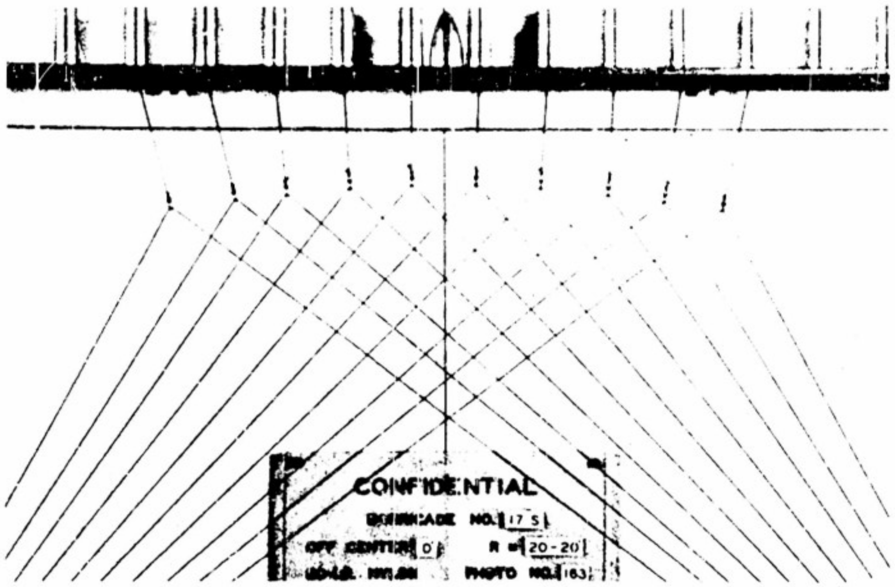


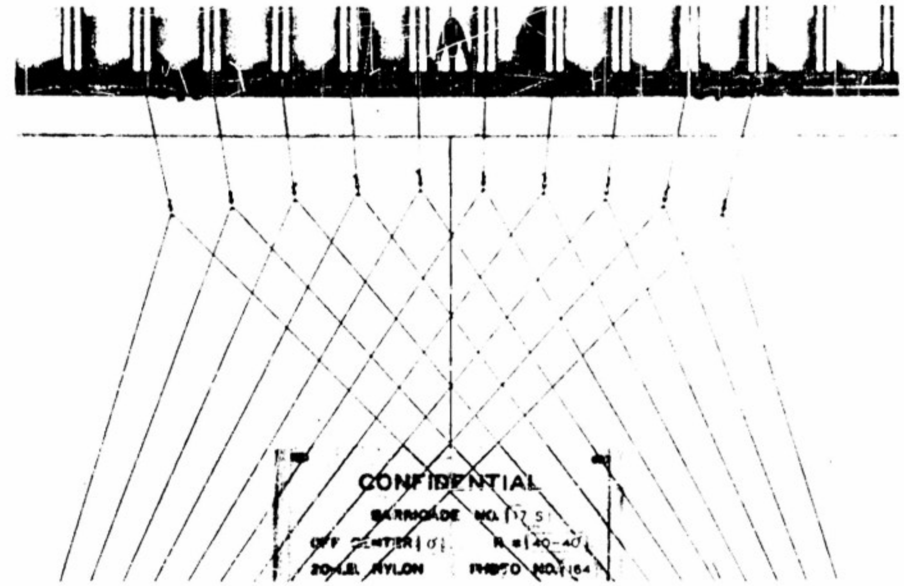


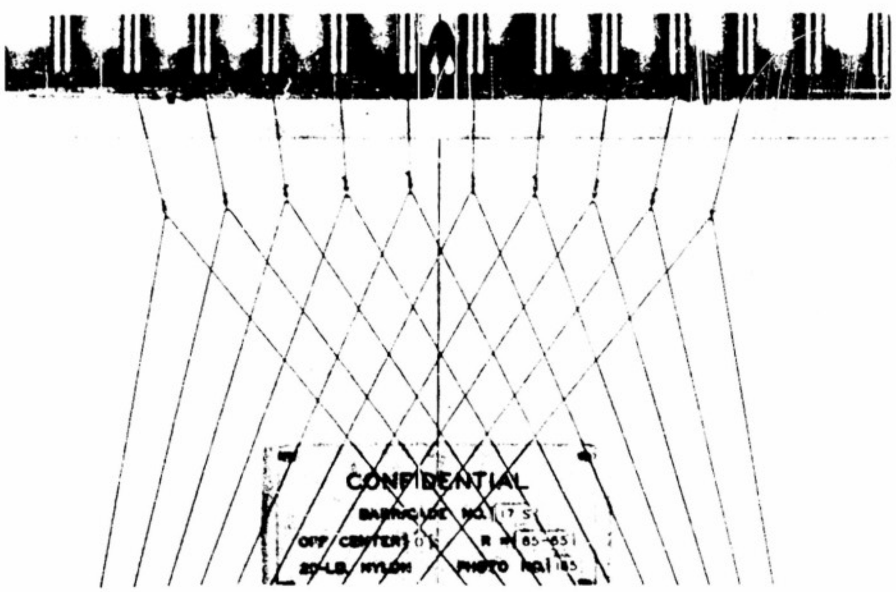
BARRICADE NO. 17 DESIGN

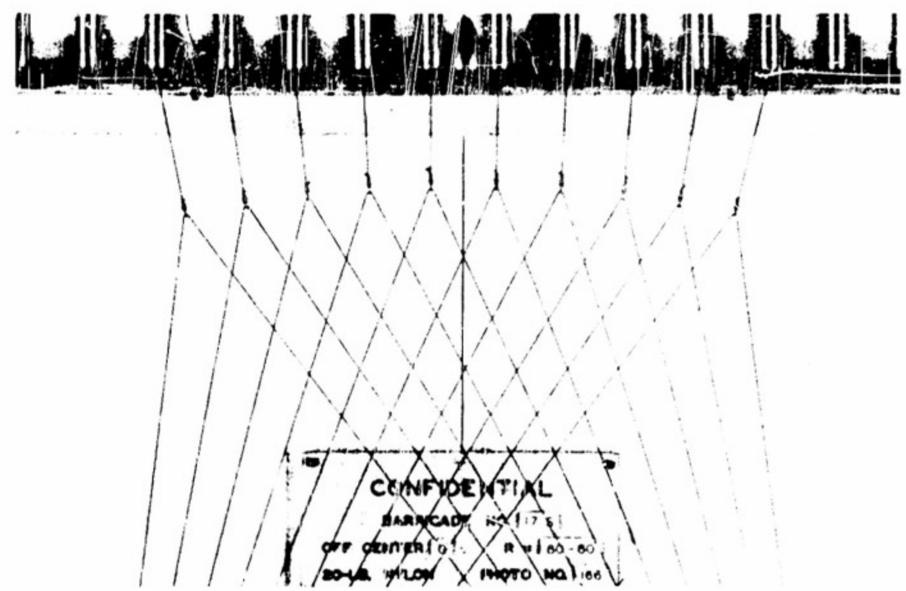
SCALE 3/16" = 1'

CONFIDENTIAL


CONFIDENTIAL
BARRICADE NO. 17 S
OFF CENTER 0'
R = 20-20
20-LB. NYLON
PHOTO NO. 163


CONFIDENTIAL
BARRICADE NO. 17 S
OFF CENTER 0'
R = 40-40
20-LB. NYLON
PHOTO NO. 164


CONFIDENTIAL
BARRICADE NO. 17 S
OFF CENTER 0'
R = 65-65
20-LB. NYLON
PHOTO NO. 165


CONFIDENTIAL
BARRICADE NO. 17 S
OFF CENTER 0'
R = 80-80
20-LB. NYLON
PHOTO NO. 166

Barricade No. 17 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	20-20	40-40	65-65	80-80
Photo No.	163	164	165	166
F_1/T	.10	.14	.18	.20
F_2/T	.14	.16	.19	.20
F_3/T	.15	.16	.17	.17
F_4/T	.18	.17	.18	.18
F_5/T	.17	.15	.15	.15
F_6/T	.16	.14	.14	.15
F_7/T	.15	.15	.15	.15
F_8/T	.16	.16	.17	.18
F_9/T	.14	.15	.20	.20
F_{10}/T	.11	.15	.19	.21
Max. ϕ	15°	12°	14°	12°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.21

Maximum angle ϕ at any runout = 15°

F_o/T at 40-foot runout = 0

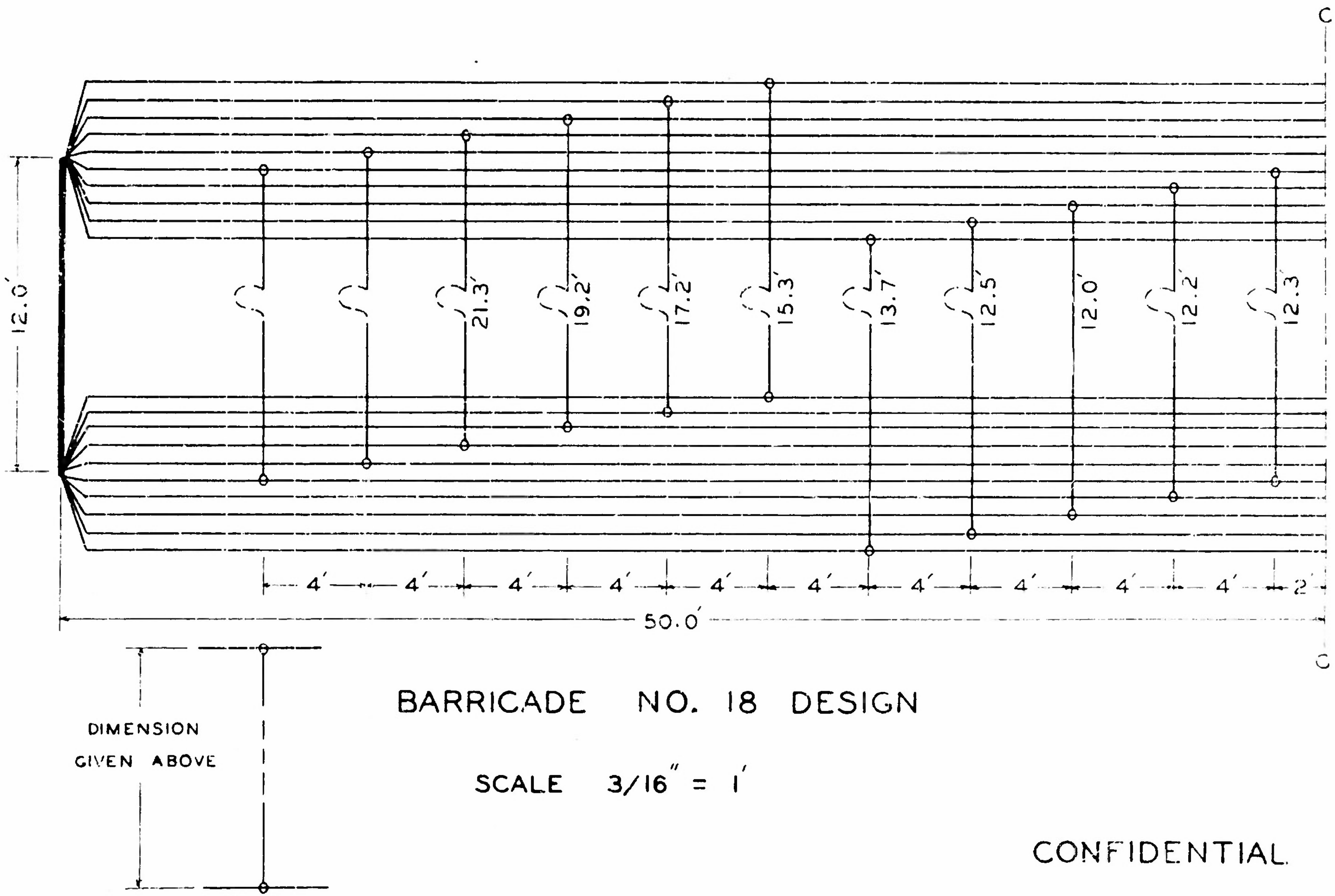
F_o/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 18

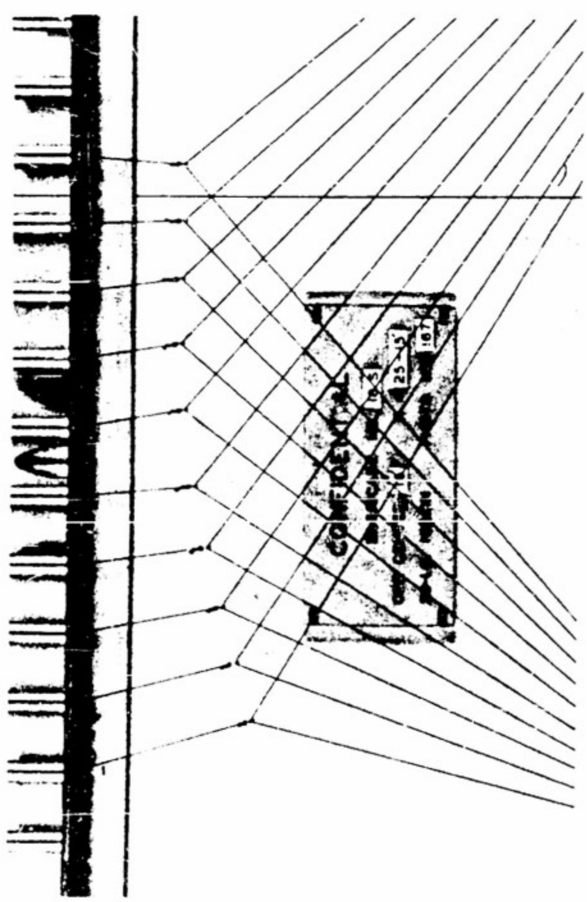
Barricade No. 18, similar to No. 17 except for the lengths of the vertical elements, was designed to equalize the forces in the vertical elements for a 16-foot off-center landing and a 40-foot runout. The design is shown on page 75. The behavior of the barricade for a 16-foot off-center landing is shown by the series of photographs on page 76 and the tabular data on page 77. The force distribution among the vertical elements is highly satisfactory, and the magnitude of the angle ϕ reasonably satisfactory. A compromise between Barricades No. 17 and No. 18 might be reasonably satisfactory for either a center or an off-center landing. Barricade No. 19, to be discussed next, represents such a compromise.



BARRICADE NO. 18 DESIGN

SCALE 3/16" = 1'

CONFIDENTIAL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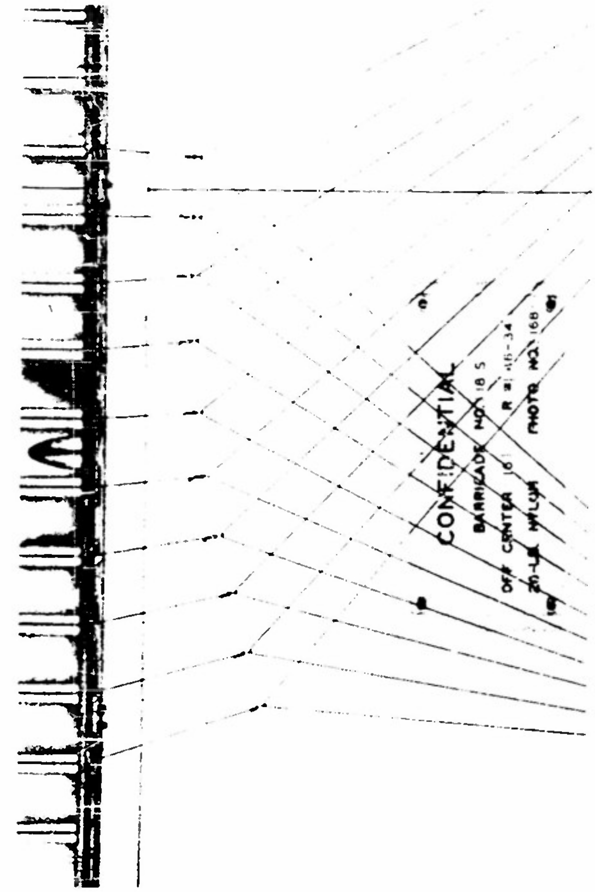
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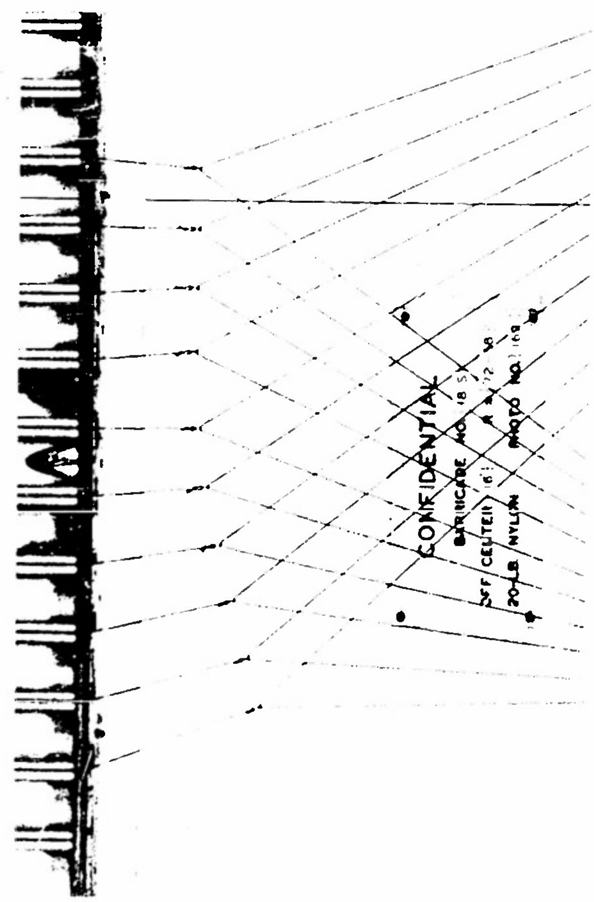
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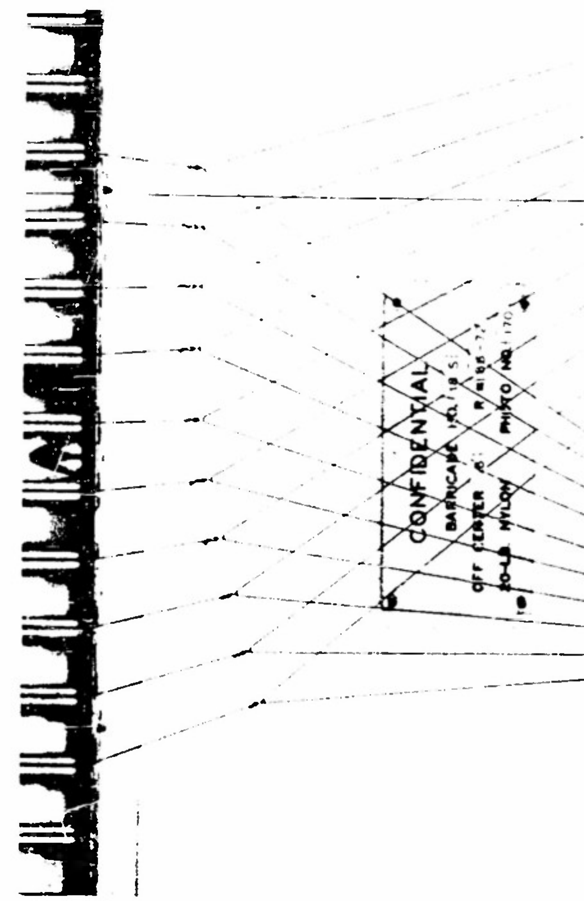

CONFIDENTIAL

Barricade No. 18 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	25-15	46-34	72-58	88-72
Photo No.	167	168	169	170
F_1/T	.13	.15	.14	.15
F_2/T	.15	.16	.15	.16
F_3/T	.13	.14	.12	.11
F_4/T	.17	.17	.16	.16
F_5/T	.17	.17	.17	.18
F_6/T	.15	.17	.18	.18
F_7/T	.13	.15	.17	.17
F_8/T	.12	.16	.17	.19
F_9/T	.08	.15	.18	.21
F_{10}/T	.06	.15	.20	.23
Max. ϕ	17°	19°	21°	21°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.23

Maximum angle ϕ at any runout = 21°

F_c/T at 40-foot runout = 0.19

F_c/T at 80-foot runout = 0.16

Torque/T at 40-foot runout = 0.6 ft.

Torque/T at 80-foot runout = 3.6 ft.

Barricade No. 19

Barricade No. 19 represents a compromise between No. 17 and No. 18, a compromise as regards the lengths of vertical elements. One would not expect it to be quite as good as No. 17 for a center landing, nor quite as good as No. 18 for a 16-foot off-center landing, but it should be reasonably good for either. It should be better than either No. 17 or No. 18 for either an 8-foot or a 24-foot off-center landing. The design of No. 19 is shown on page 80.

The behavior of this barricade is illustrated by the series of photographs on pages 81, 82 and 83 for 0, 16 and 24-foot off-center landings respectively, the arresting engine being singly reeved in each case. The corresponding data are shown in the tables on pages 84-86. Data for a 16-foot off-center landing with a doubly reeved engine are given in the table on page 87, although illustrative photographs are not shown for this case.

By way of comparing Barricade No. 19 with Barricade Nos. 10 and 11, the following table and comments are offered:

Comparison of Barricade Nos. 10, 11 and 19

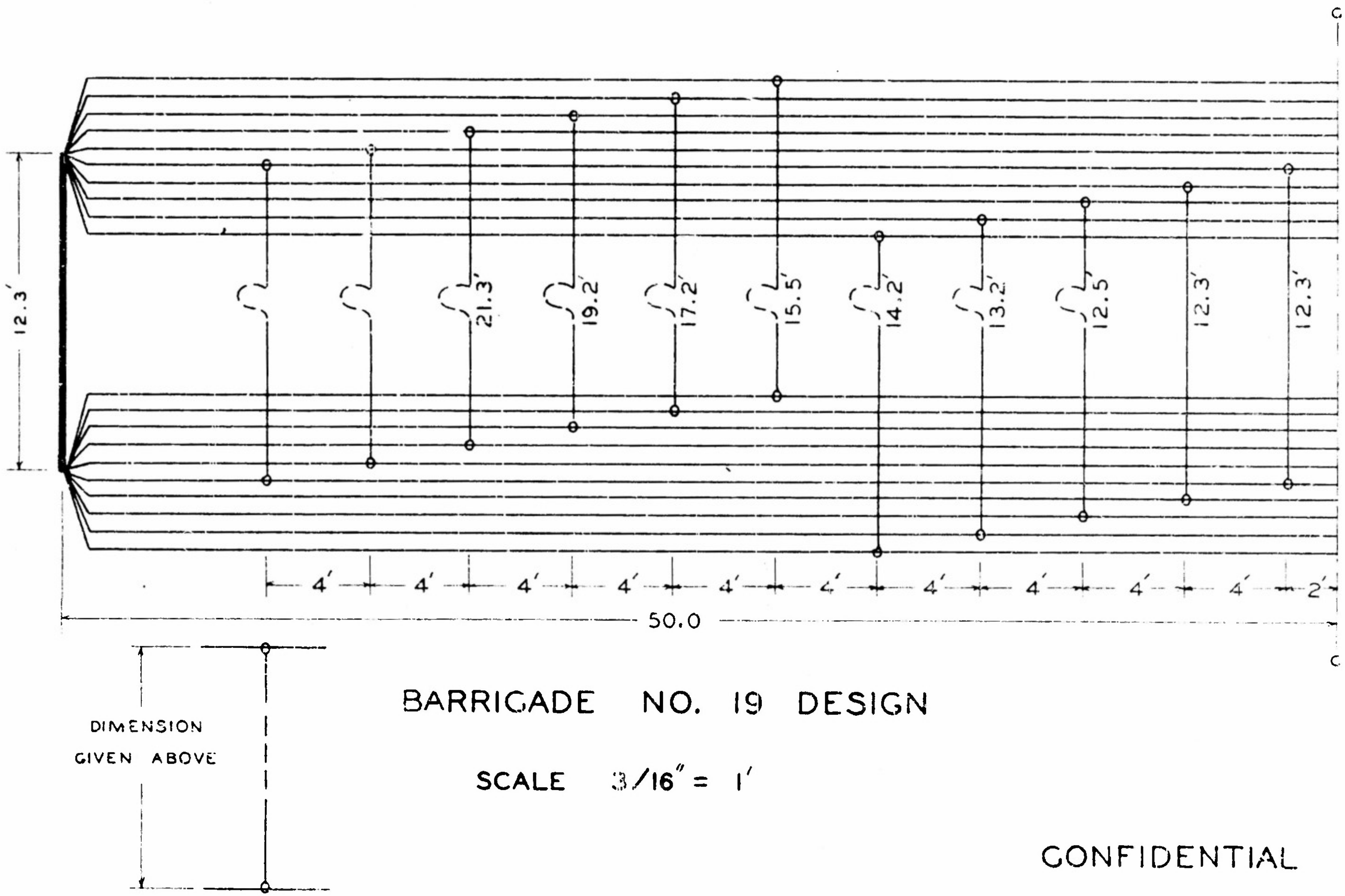
Distance Off Center		Barricade No. 10	Barricade No. 11	Barricade No. 19
0 ft.	Max. F/T	0.30	0.26	0.26
	Max. Ø	37°	33°	15°
	Torque/T*	0	0	0
	Reference#	47	60	84
16 ft.	Max. F/T	0.47	0.27	0.25
	Max. Ø	40°	44°	21°
	Torque/T*	-7.3 ft.	0.5 ft.	0.3 ft.
	Reference#	49	62	85
24 ft.	Max. F/T	0.57	0.31	0.34
	Max. Ø	44°	47°	28°
	Torque/T*	-8.6 ft.	1.5 ft.	3.4 ft.
	Reference#	50	63	86

* At a runout of 40 feet.
\# Values are taken from tables on pages indicated.

1. A real reduction in the angle Ø has been accomplished in Barricade No. 19, without appreciable sacrifice as regards the force distribution or the torque exerted.

2. Considering the force distributions among the vertical elements, the angles at which these forces act, and the torques exerted on the plane, Barricade No. 19 represents a distinct improvement over No. 11, and an even greater improvement over No. 10.

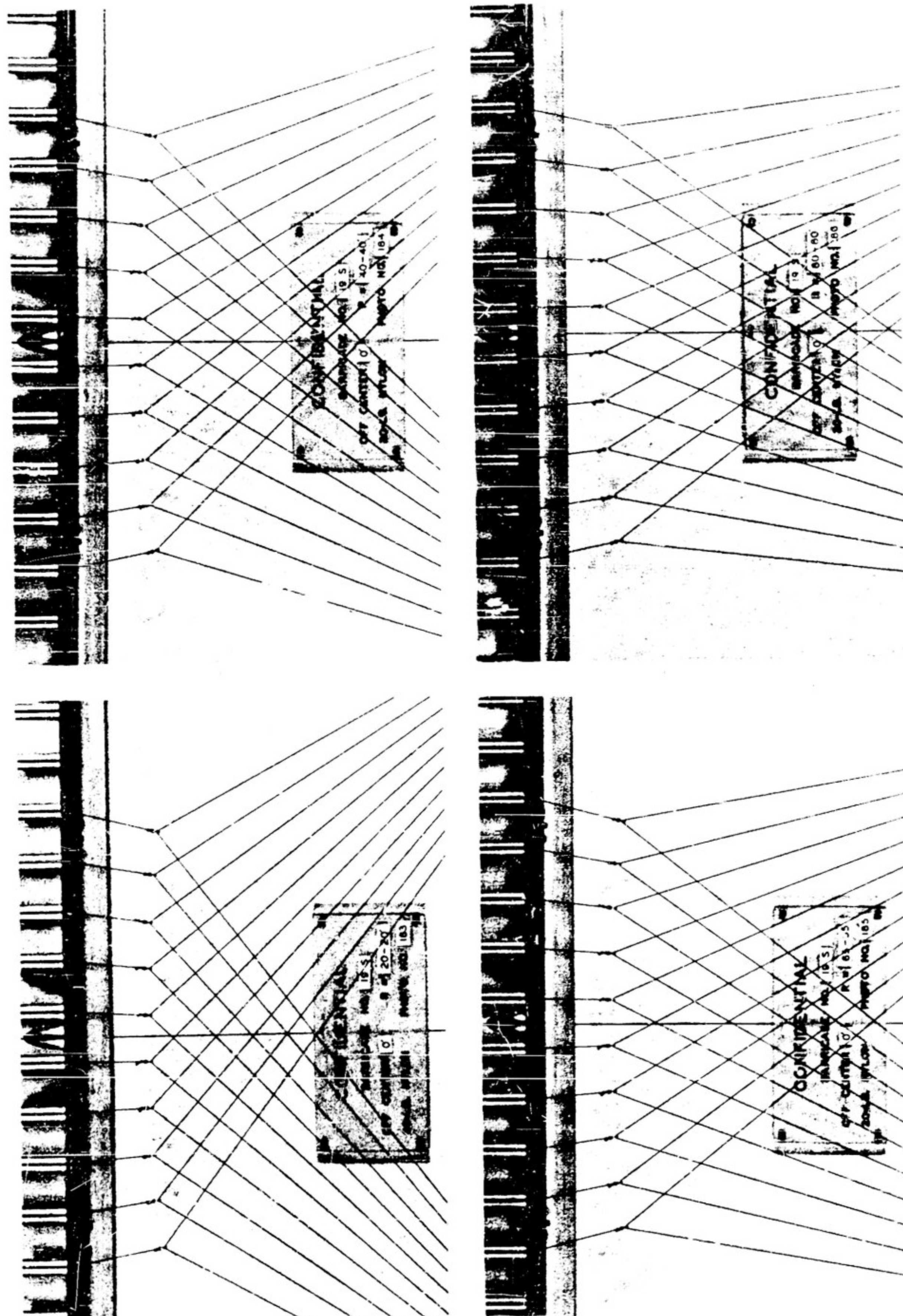
3. There are two respects in which No. 19 is inferior to both No. 10 and No. 11. With No. 19 there is a much greater chance of entanglement of the longitudinal elements with the tail fin of the plane. Also, for a landing in which the fuselage of the plane is not parallel to the center line of the landing deck, the force distribution would be less favorable for No. 19 than for No. 10 or No. 11.



BARRICADE NO. 19 DESIGN

SCALE 3/16" = 1'

CONFIDENTIAL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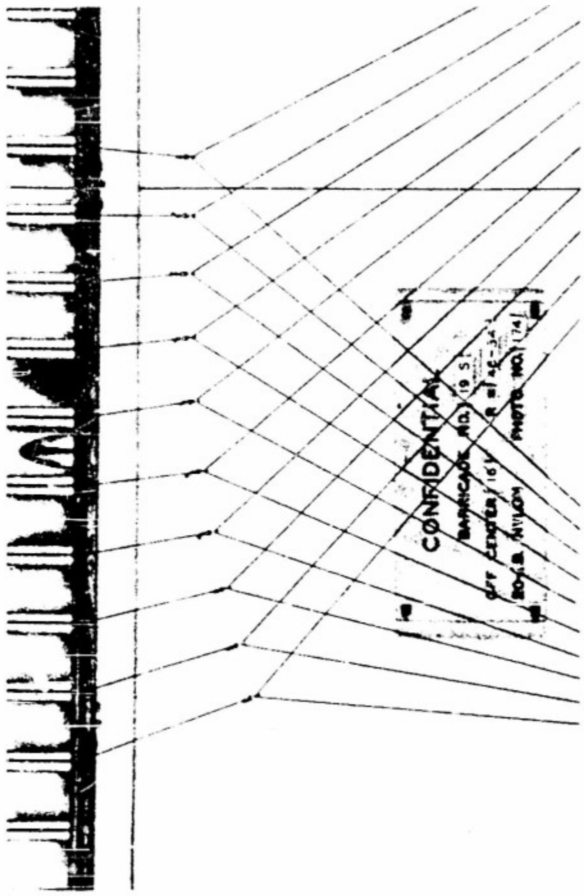
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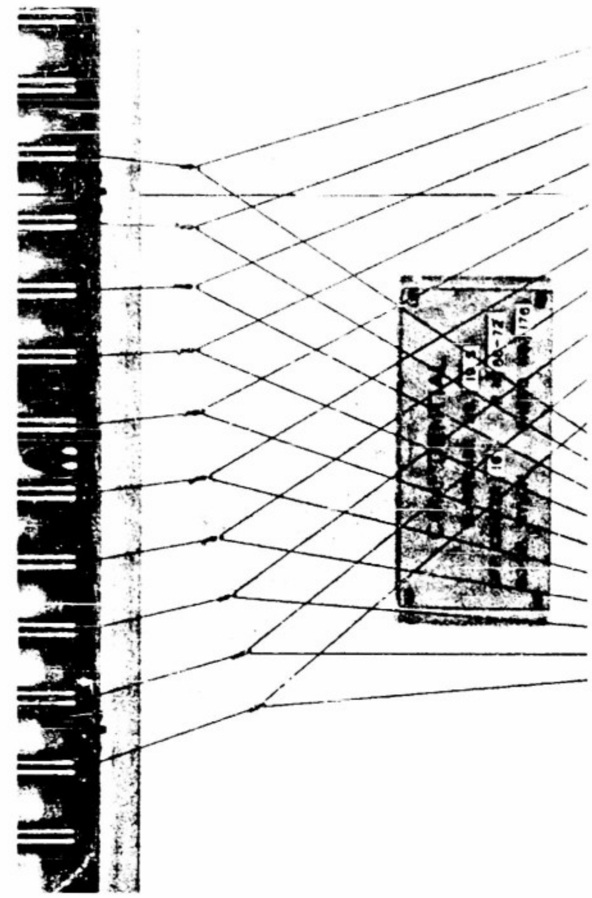
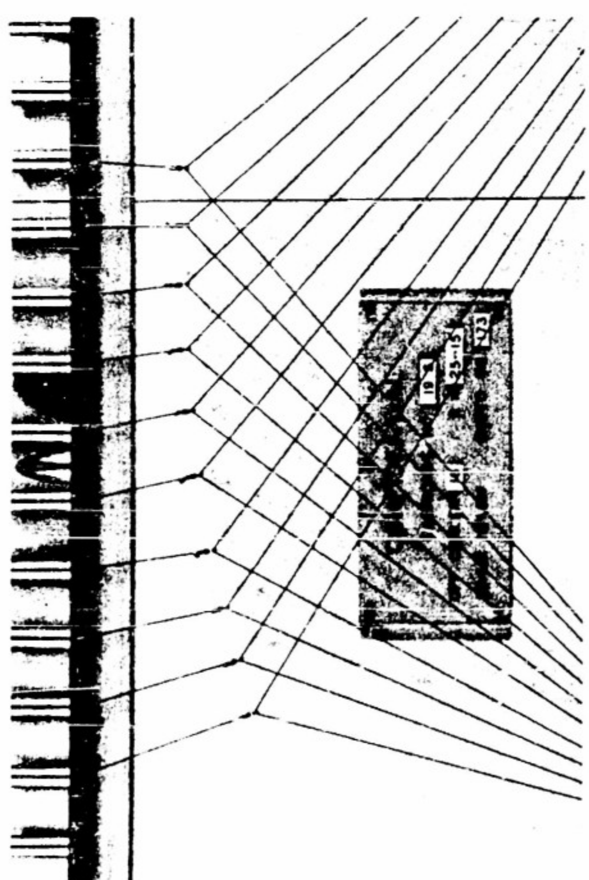
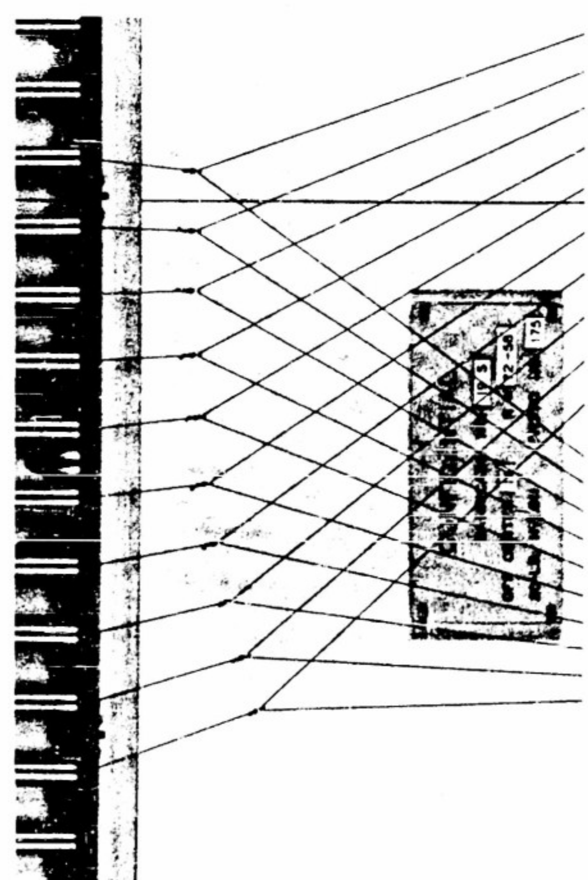
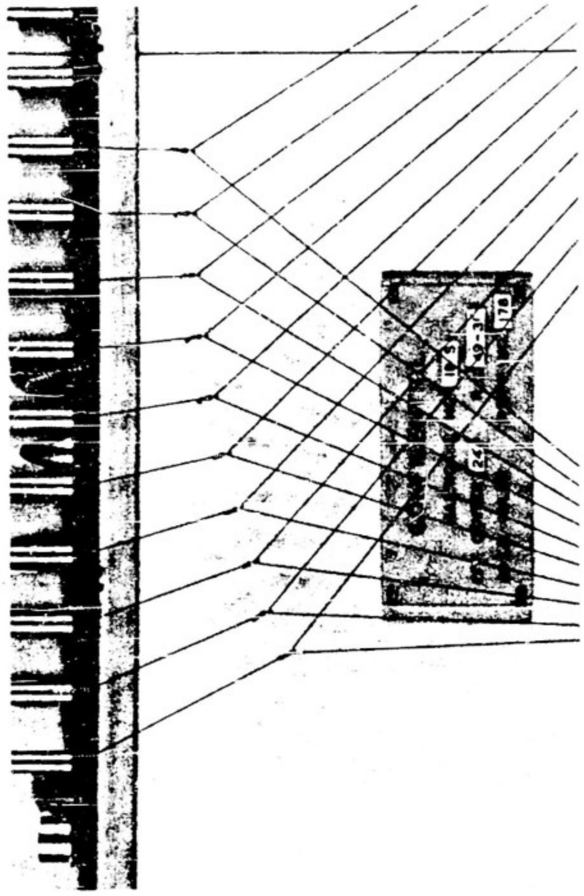
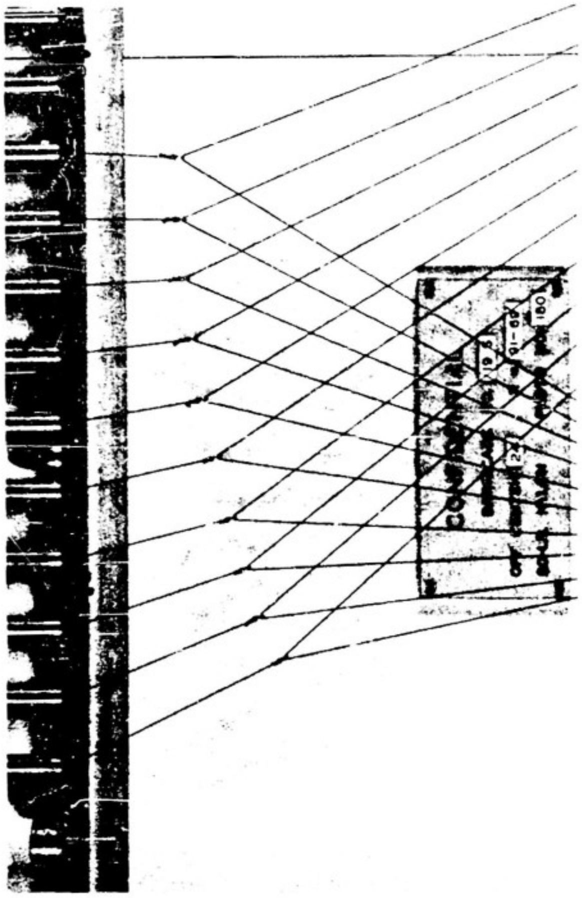
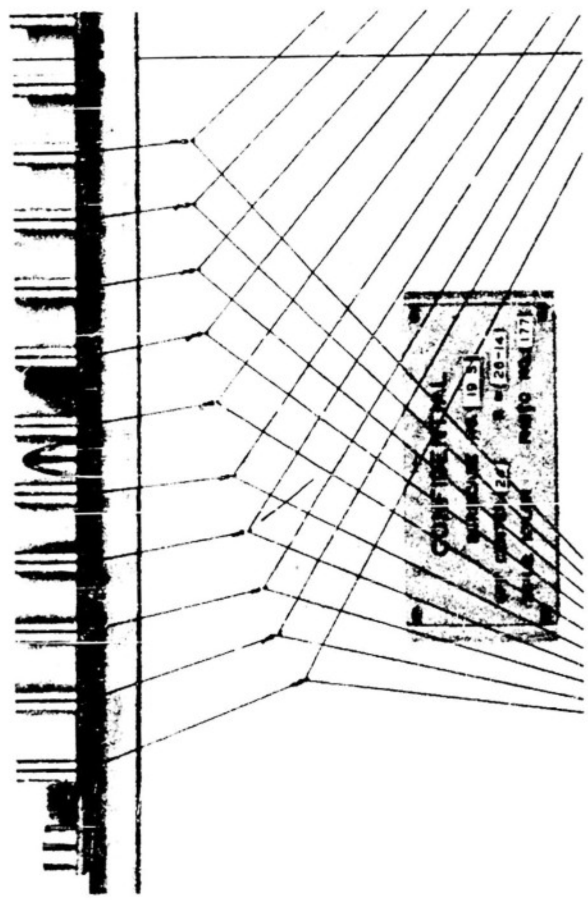


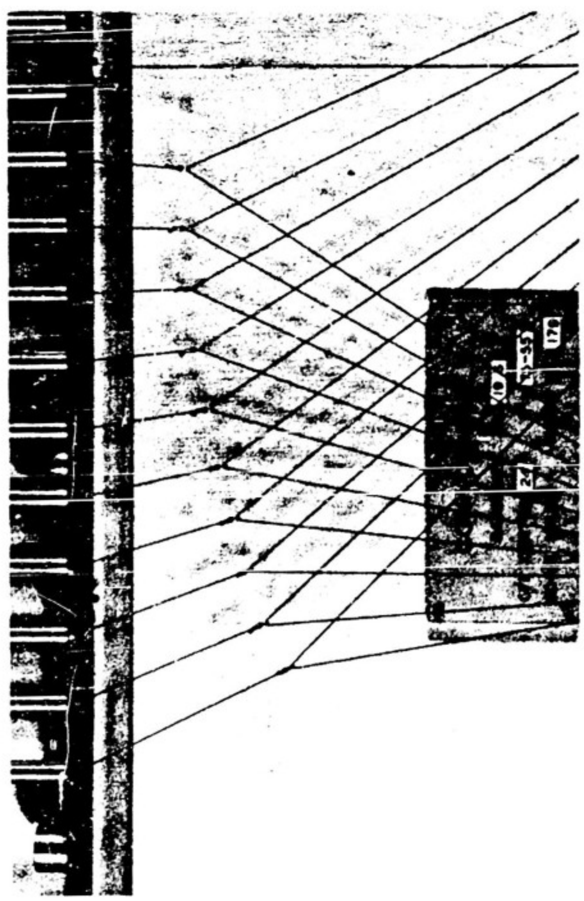












Barricade No. 19 S (or D)

Plane Wings Straight

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	20-20	40-40	65-65	80-80
Photo No.	183	184	185	186
F_1/T	.14	.18	.25	.26
F_2/T	.16	.19	.24	.24
F_3/T	.15	.16	.18	.19
F_4/T	.12	.12	.11	.12
F_5/T	.08	.07	.08	.08
F_6/T	.08	.07	.08	.08
F_7/T	.11	.10	.10	.11
F_8/T	.16	.17	.19	.19
F_9/T	.18	.21	.25	.25
F_{10}/T	.15	.21	.26	.26
Max. ϕ	11°	11°	15°	12°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.26

Maximum angle ϕ at any runout = 15°

F_c/T at 40-foot runout = 0

F_c/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 19 S

Plane Wings Straight

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	25-15	46-34	72-58	88-72
Photo No.	173	174	175	176
F_1/T	.14	.18	.18	.17
F_2/T	.16	.19	.18	.17
F_3/T	.14	.15	.16	.15
F_4/T	.16	.16	.17	.17
F_5/T	.12	.14	.15	.13
F_6/T	.12	.13	.15	.15
F_7/T	.11	.13	.15	.15
F_8/T	.12	.16	.19	.20
F_9/T	.12	.17	.23	.24
F_{10}/T	.09	.17	.24	.25
Max. ϕ	21°	21°	20°	19°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.25

Maximum angle ϕ at any runout = 21°

F_o/T at 40-foot runout = 0.23

F_o/T at 80-foot runout = 0.16

Torque/T at 40-foot runout = 0.3 ft.

Torque/T at 80-foot runout = 3.4 ft.

Barricade No. 19 S

Plane Wings Straight

Singly Reeved
24-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	26-14	49-31	75-55	91-69
Photo No.	177	178	179	180
F_1/T	.21	.23	.21	.20
F_2/T	.17	.18	.17	.17
F_3/T	.10	.09	.08	.07
F_4/T	.12	.11	.10	.10
F_5/T	.13	.12	.11	.10
F_6/T	.14	.15	.16	.15
F_7/T	.14	.15	.16	.16
F_8/T	.14	.18	.20	.21
F_9/T	.14	.20	.25	.26
F_{10}/T	.17	.26	.32	.34
Max. Ø	22°	28°	26°	26°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.34

Maximum angle Ø at any runout = 28°

F_c/T at 40-foot runout = 0.28

F_c/T at 80-foot runout = 0.25

Torque/T at 40-foot runout = 3.4 ft.

Torque/T at 80-foot runout = 6.8 ft.

Barricade No. 19 D

Plane Wings Straight

Doubly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	20	40	65	80
Photo No.	198	199	200	201
F_1/T	.14	.17	.16	.15
F_2/T	.17	.19	.18	.17
F_3/T	.13	.13	.13	.12
F_4/T	.16	.16	.16	.15
F_5/T	.14	.15	.15	.14
F_6/T	.13	.13	.14	.13
F_7/T	.11	.13	.14	.14
F_8/T	.12	.14	.17	.17
F_9/T	.14	.19	.23	.25
F_{10}/T	.12	.21	.27	.28
Max. ϕ	22°	20°	22°	22°
Element	#1	#1	#1	#1

Maximum F/T at any runout = 0.28

Maximum angle ϕ at any runout = 23°

F_c/T at 40-foot runout = 0.18

F_c/T at 80-foot runout = 0.14

Torque/T at 40-foot runout = 1.3 ft.

Torque/T at 80-foot runout = 4.5 ft.

SUMMARY OF BARRICADE CHARACTERISTICS (STRAIGHT WINGS)

Collected in the following table are the measured characteristics of all barricades studied which were designed for stopping planes for which the leading edge of the wing is perpendicular to the fuselage. Let it be emphasized again that no allowance has been made for the fact that the wings of even conventional planes are swept back slightly, nor for the fact that the wing is thicker near the fuselage than near the tip. It has appeared advisable to keep all measurements on a common basis, that of a straight, very thin wing. Approximate allowance for a small angle of sweepback and the variable thickness of the wing can easily be made in specifying the lengths of the vertical elements for any particular barricade one desires to construct.

Comparison of Barricades (Straight Wings)

Bar. No.	Off Center	Max. F/T	Max. ϕ	F_c/T		Torque/T	
				R=40'	R=80'	R=40'	R=80'
1 S	0 16	.99 1.04	7° 18°	0 .44	0 .29[a]	0 4.5	0 2.4[a]
1 D	0 16	.99 2.00	7° 22°	0 -.48[b]	0 -.33	0 -36[b]	0 -36
2A S	0	.37	5°	0	0	0	0
2 S	0 16	.36 .90	11° 19°	0 .07	0 .11[c]	0 17	0 14[c]
8 S	16[d]	.38	22°	.24	.20[c]	.5	1.2[c]
9 S	0 16	.35 .40	11° 16°	0 .24	0 .21	0 .3	0 1.5
10 S	0 8• 16 24	.30 .25 .47 .57	37° 35° 40° 44°	0 .12 .32 .42	0 .70 .34	0 .9 - 7.3 - 8.6	0 - 5.4 - 5.1
10 D	0 16[a] 24[a]	.30 .50 .56	37° 42° 44°	0 .41 .50	0 .14 .37	0 - 6.3 - 9.2	0 - 6.4 - 5.6

(Continued)

Comparison of Barricades (Continued)

Bar. No.	Off Center	Max. F/T	Max. ∅	F_o/T		Torque/T	
				R=40'	R=80'	R=40'	R=80'
11 S	0	.26	33°	0	0	0	0
	8[e]	.23	33°	.14		.4	
	16	.27	44°	.23	.23	.5	2.5
	24	.31	47°	.31	.36	1.5	4.5
11 D	0	.26	33°	0	0	0	0
	8[e]	.23	36°	.08		.6	
	24	.30	48°	.34	.23	1.5	4.7
16 S	0	.78	25°	0	0	0	0
17 S	0	.21	15°	0	0	0	0
18 S	16	.23	21°	.19	.16	.6	.4
19 S	0	.26	15°	0	0	0	0
	16	.25	21°	.23	.16	.3	3.4
	24	.34	28°	.28	.25	3.4	6.8
19 D	0	.26	15°	0	0	0	0
	16	.28	23°	.18	.14	1.3	4.5

a. Data are for a runout of 78 feet rather than 80 feet.
b. Data are for a runout of 45 feet rather than 40 feet.
c. Data are for a runout of 84 feet rather than 80 feet.
d. Data were taken at only one runout, 42 feet.
e. Data were taken at only one runout, [illegible]0 feet.

BARRICADES FOR PLANES WITH SWEPTBACK WINGS.

To this point attention has been directed toward the stopping of planes having conventional straight wings. The prospect of having to stop planes with wings swept back from 45° to 60° presents an additional immediate problem. General considerations of this problem have convinced the group that in stopping such planes certain barricade elements must be constructed to sustain considerably larger forces than those encountered in stopping conventional planes.

For the same reasons as in the case of the conventional plane, it appears advisable here also to engage the wings or the fuselage. Even though they are swept back, the wings are probably more easily engaged than the fuselage. The larger the angle of sweepback the more difficult it will be to engage the wings. Likewise, the larger the angle of sweepback the larger will be the maximum forces which must be sustained by certain barricade elements. Some observations have been made for planes with wings swept back both 45° and 60°. (The angle of sweepback used throughout this report is the angle the leading edge of either wing makes with a horizontal line drawn perpendicular to the axis of the fuselage.) While the results fall far short of suggesting a really satisfactory barricade, they do suggest designs which may be tolerated.

Information to be presented on sweptback wing engagements was obtained in the same manner as that for straight wing engagements. A model representing the leading edge of the sweptback wing was simply substituted for the previous model. It appeared interesting to investigate first an engagement with Barricade No. 10, since this barricade is of essentially the same design as the one in current use for conventional planes.

Barricade No. 10

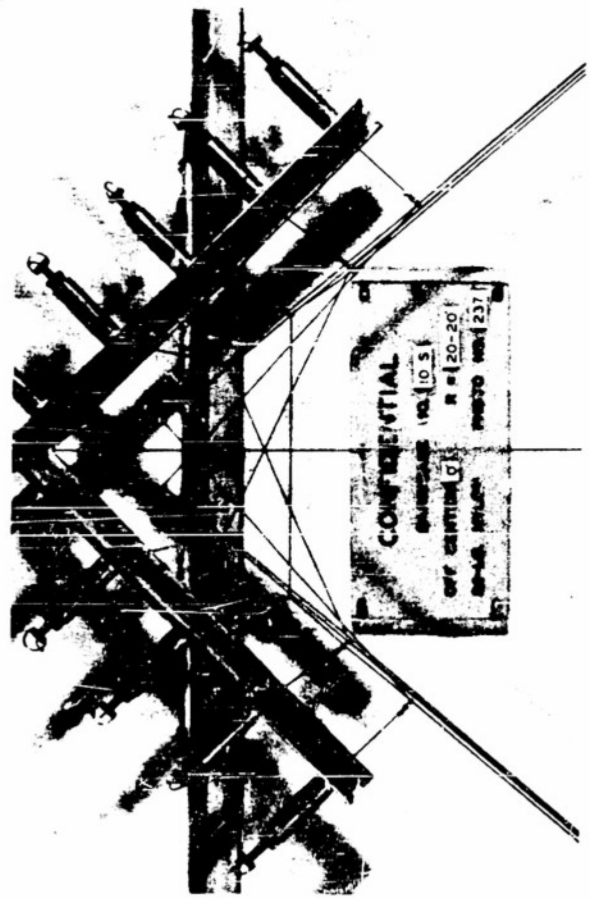
The design of this barricade (essentially that now in use for straight-wing planes) has already been described, and a diagram has been shown on page 41. The behavior of the barricade upon engaging a plane with wings swept back 45° in a center landing and a 16-foot off-center landing is illustrated by the series of photographs on pages 92 and 93. Corresponding tabular data are shown on page 94. Behavior of the barricade upon engaging a plane with wings swept back 60° in a center landing and a 16-foot off-center landing is illustrated by the photographs on pages 95 and 96. Corresponding data are shown on page 97.

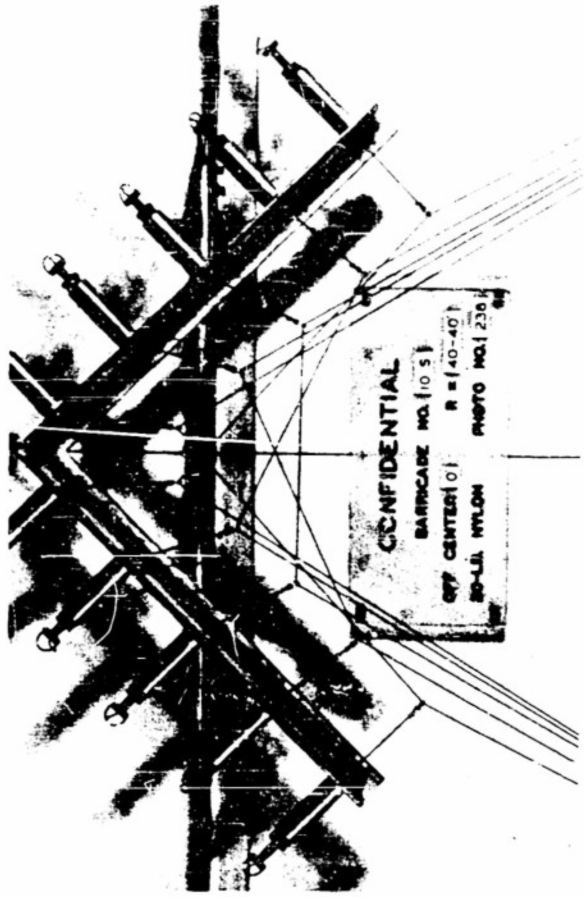
At first sight neither the photographs nor the tabular data indicate satisfactory operation. By far the major force is exerted by the two centrally located vertical elements. Furthermore, the angle ϕ for these two forces is undesirably large. The table on page 98 summarizes the relative merits of

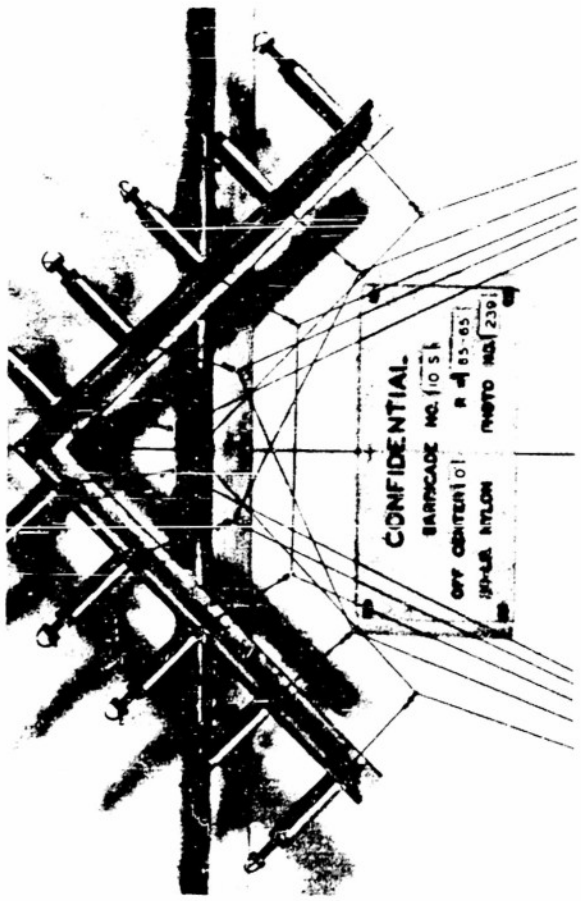
Barricade No. 10 for both center and 16-foot off-center landings of planes with straight wings, planes with wings swept back 45° and planes with wings swept back 60°. Additional observations not tabulated here show that at a 40-foot runout of a plane with wings swept back 45° engaging the barrier 24 feet off center:- The maximum F/T is 0.53; the maximum angle Ø is 31°; the F_c/T is 0.39; the torque/T is -3.5 feet. In view of this statement, coupled with the values given in the table on page 98, it is difficult to escape the conclusion that for any off-center landing up to 24 feet, Barricade No. 10 would work about as well for a plane with a sweepback of 45° as for a 24-foot off-center landing of a plane with straight wings. Either center or off-center engagements of a plane with wings swept back 60° lead to considerably larger maximum values of F/T and of Ø.

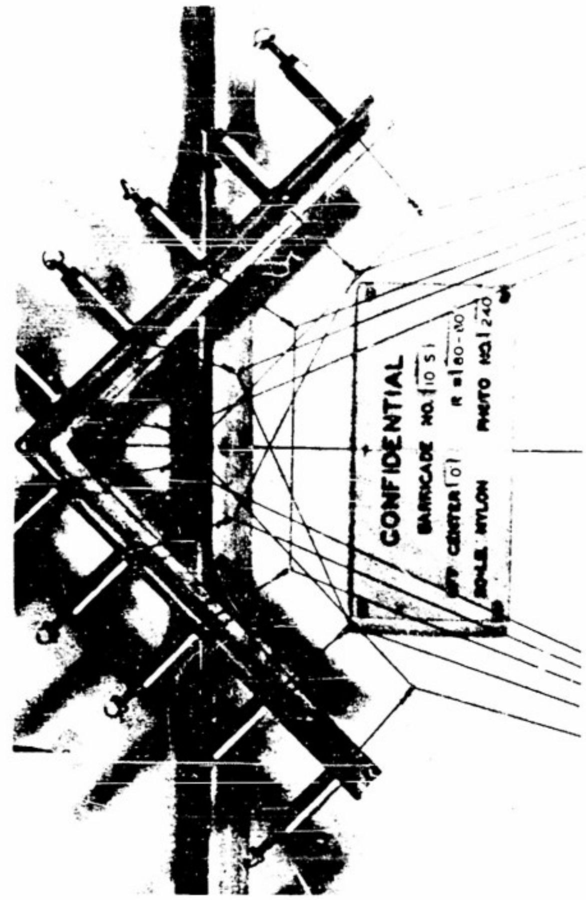
In all probability, dynamic considerations are of greater importance in judging the behavior of a barricade during an engagement with sweptback wings than during a similar engagement with straight wings. The sweptback wings will always engage first those elements nearest the center of the plane. The impact will force these elements farther from the center. If this occurs only to a limited extent it will reduce the maximum angle Ø and may reduce the maximum F/T. It will definitely lead to a more favorable force distribution among the vertical elements. If necessary, the extent of this effect can be limited by a flexible tie between successive vertical elements operating on the same pair of longitudinal elements. Use of such a tie would have a tendency to bring all pairs of vertical elements into a more nearly symmetrical position with respect to the plane.

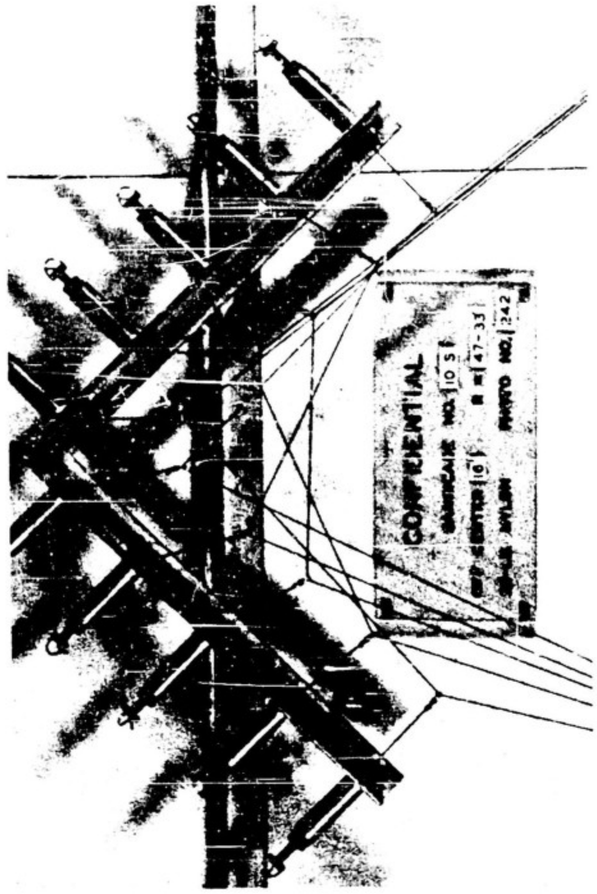
It thus appears that Barricade No. 10 might be at least reasonably satisfactory for stopping a plane with wings swept back 45°. It would probably stop planes with wings swept back 60° satisfactorily if the strengths of the vertical elements of the barricade were doubled. With the hope of arriving at a still more satisfactory barricade, particularly for planes having wings swept back 60°, several barricades designated as Nos. 13, 15, 20, 21, 22 and 23 were investigated.

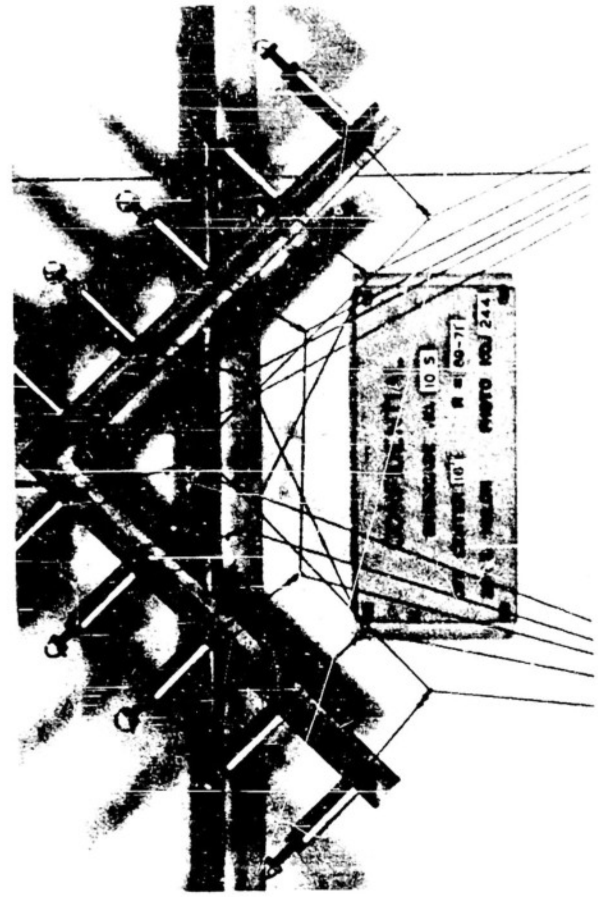

CONFIDENTIAL
BARRICADE NO. 10 5
R = 20-20
PHOTO NO. 237

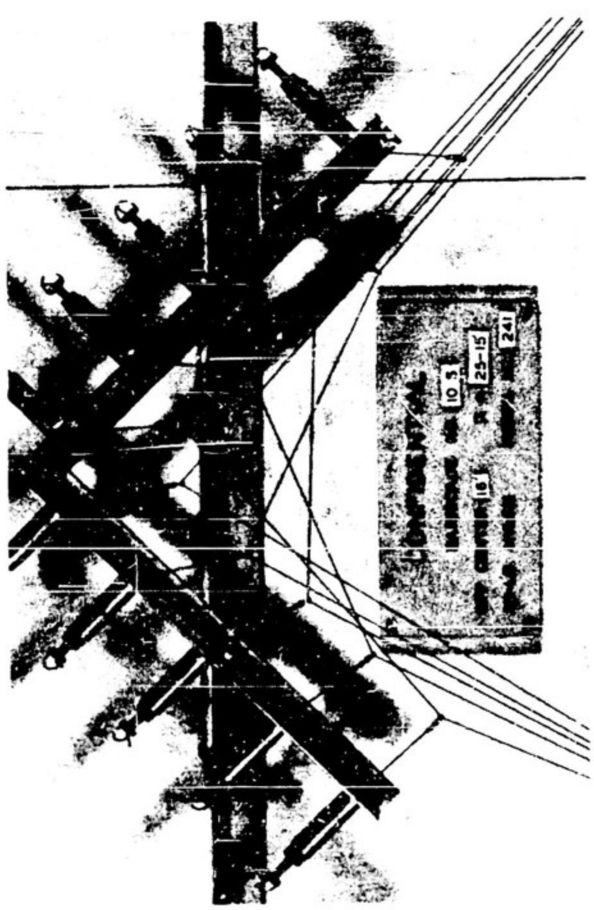

CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 0
R = 40-40
50-LB. NYLON
PHOTO NO. 238

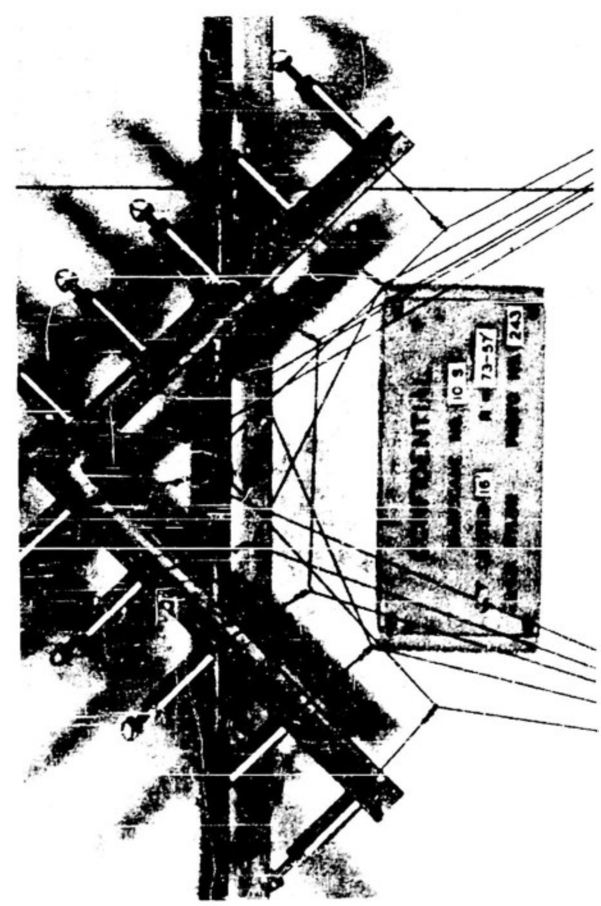

CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 0
R = 65-65
50-LB. NYLON
PHOTO NO. 239


CONFIDENTIAL
BARRICADE NO. 10 5
OFF CENTER 0
R = 80-80
50-LB. NYLON
PHOTO NO. 240


CONFIDENTIAL
10 5
47-33
PHOTO NO. 242


10 5
244


10 5
25-15
241


10 5
73-57
243

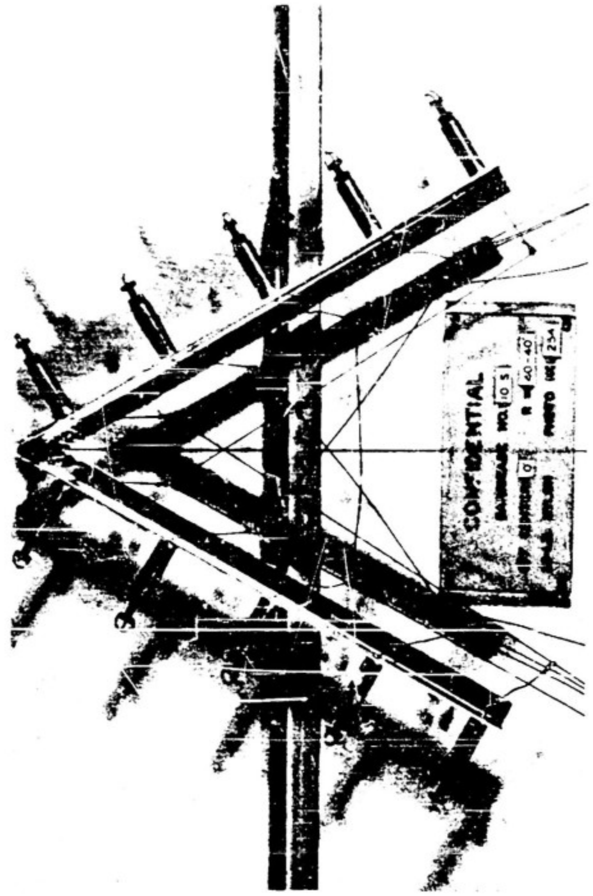
Barricade No. 10 S

Plane Wings Swept Back 45°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	25-15	47-33	73-57	89-71
Photo No.	237	238	239	240	241	242	243	244
F_1/T	.04	.12	.15	.17	.14	.22	.27	.28
F_2/T	.03	.05	.06	.07	.07	.10	.11	.11
F_3/T	0	0	.01	.01	.01	.01	.02	.25
F_4/T	.09	.12	.11	.13	.13	.12	.12	.13
F_5/T	.50	.55	.51	.54	.44	.46	.44	.48
F_6/T	.50	.55	.51	.54	.43	.46	.50	.52
F_7/T	.09	.12	.12	.13	.10	.16	.17	.18
F_8/T	0	0	.01	.01	.01	.01	.01	.02
F_9/T	.03	.05	.06	.07	.02	.02	.04	.05
F_{10}/T	.04	.11	.15	.17	0	.03	.09	.12
Max. Ø	44°	42°	39°	37°	49°	46°	41°	39°
Element	#5	#5	#5	#5	#6	#6	#6	#6

	On Center	16 ft. Off Center
Maximum F/T at any runout	0.55	0.52
Maximum angle Ø at any runout	44°	49°
F_c/T at 40-foot runout	0	0.28
F_c/T at 80-foot runout	0	0.31
Torque/T at 40-foot runout	0	-3.6 ft.
Torque/T at 80-foot runout	0	-4.1 ft.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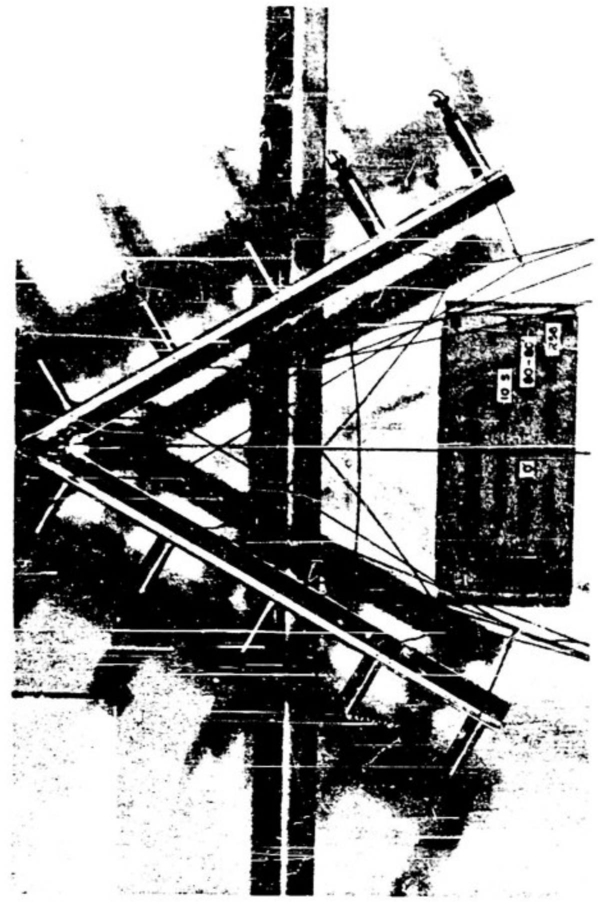
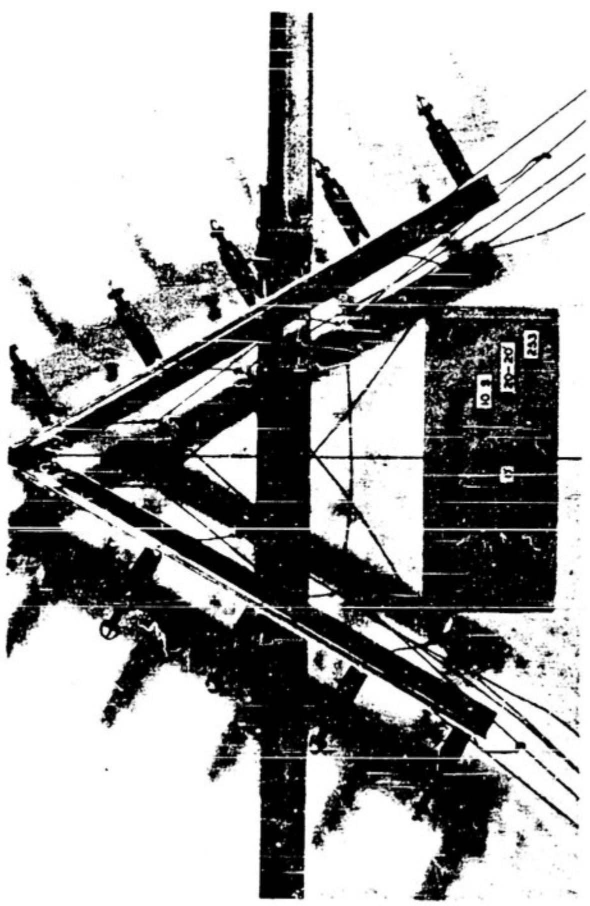
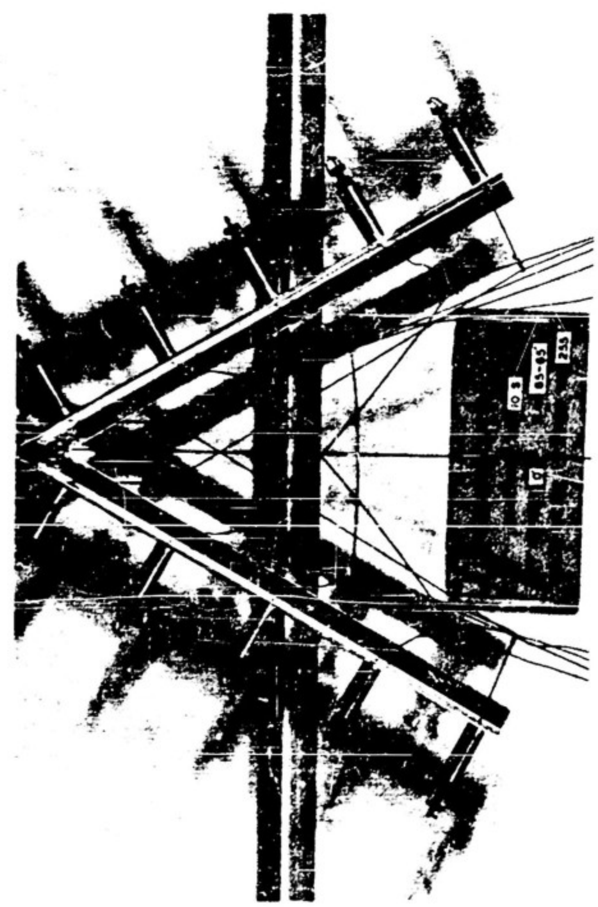
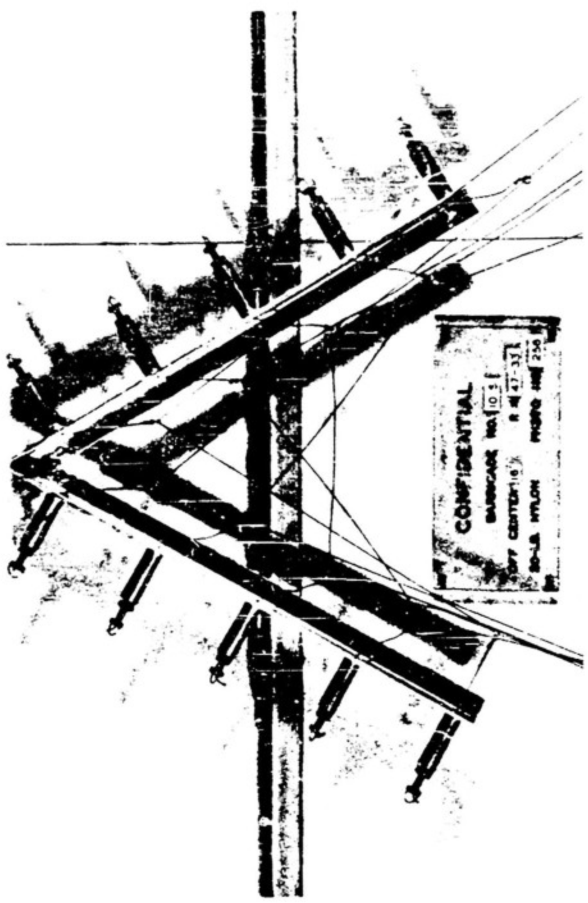
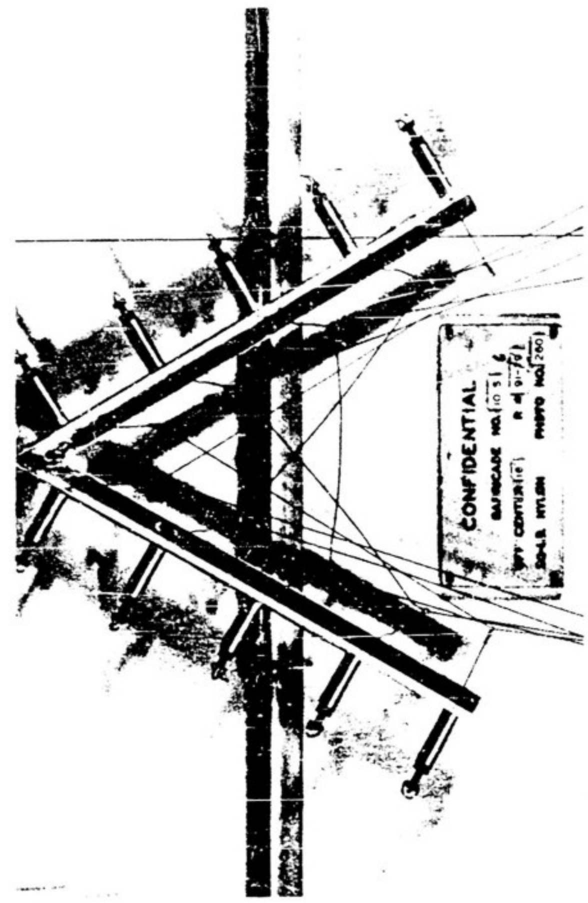







CONFIDENTIAL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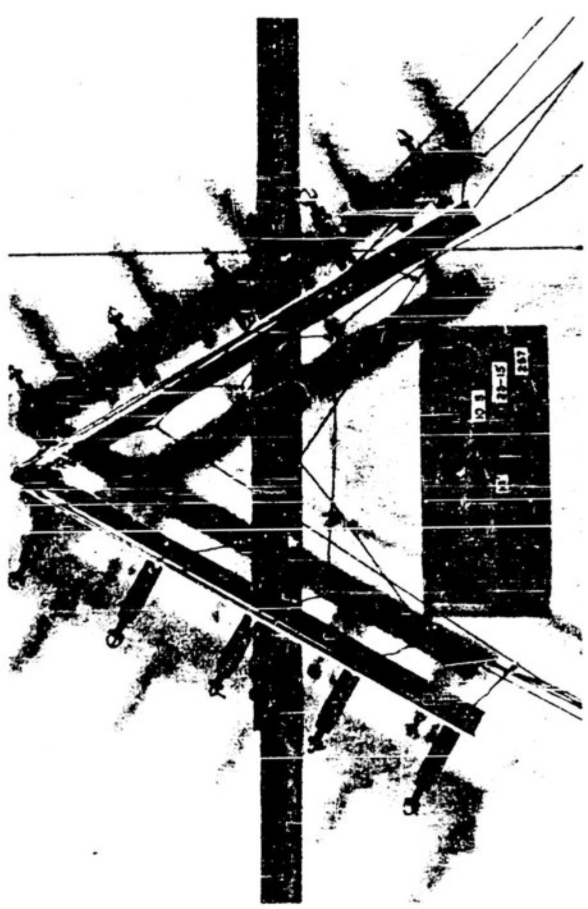
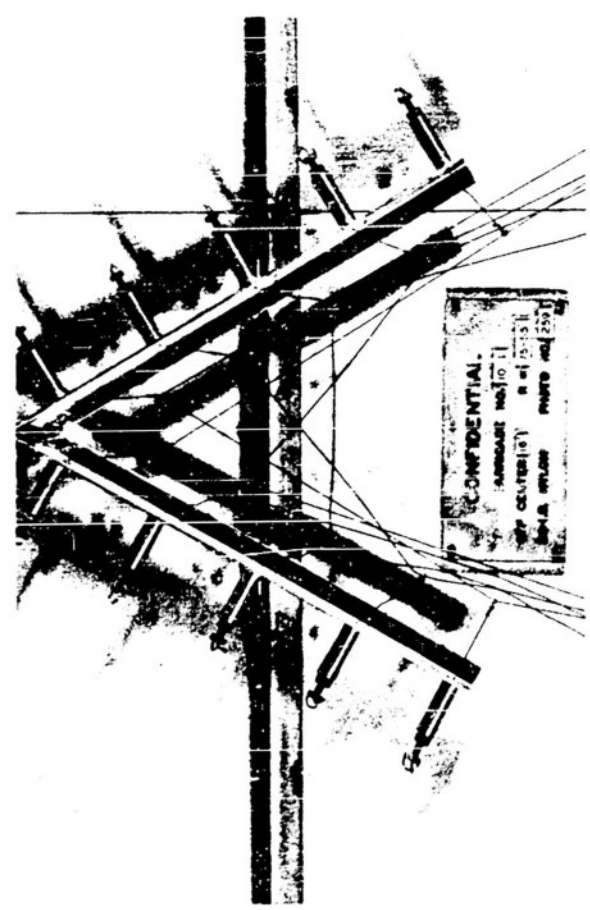



CONFIDENTIAL

Barricade No. 10 S

Plane Wings Swept Back 60°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	25-15	47-33	75-55	91-69
Photo No.	253	254	255	256	257	258	259	260
F_1/T	0	0	.07	.10	0	.08	.15	.16
F_2/T	0	0	0	0	0	0	0	0
F_3/T	0	0	0	0	0	0	0	0
F_4/T	0	0	0	0	0	0	0	0
F_5/T	.78	.86	.89	.90	.79	.87	.91	.92
F_6/T	.78	.86	.89	.90	.77	.83	.86	.87
F_7/T	0	0	0	0	0	0	0	0
F_8/T	0	0	0	0	0	0	0	0
F_9/T	0	0	0	0	0	0	0	0
F_{10}/T	0	0	.08	.11	0	0	0	.02
Max. Ø	60°	62°	61°	60°	67°	64°	63°	62°
Element	#5	#5	#5	#5	#6	#6	#6	#6

	On Center	16 ft. Off Center
Maximum F/T at any runout	0.90	0.92
Maximum angle Ø at any runout	62°	67°
F_c/T at 40-foot runout	0	0.23
F_c/T at 80-foot runout	0	0.24
Torque/T at 40-foot runout	0	1.2 ft.
Torque/T at 80-foot runout	0	-1.1 ft.

Barricade No. 10 S

	Straight Wings			Wings Swept Back 45°		Wings Swept Back 60°	
	On Center	16 ft. Off Center	24 ft. Off Center	On Center	16 ft. Off Center	On Center	16 ft. Off Center
Maximum F/T at any runout	0.30	0.47	0.57	0.55	0.52	0.90	0.92
Maximum angle ϕ at any runout	37°	40°	44°	44°	49°	62°	67°
F_c/T at 40-foot runout	0	0.32	0.42	0	0.28	0	0.23
F_c/T at 80-foot runout	0	0.70	0.34	0	0.31	0	0.24
Torque/T at 40-foot runout	0	-7.3	-8.6	0	-3.6	0	1.2
Torque/T at 80-foot runout	0	-5.4	-5.1	0	-4.1	0	-1.1

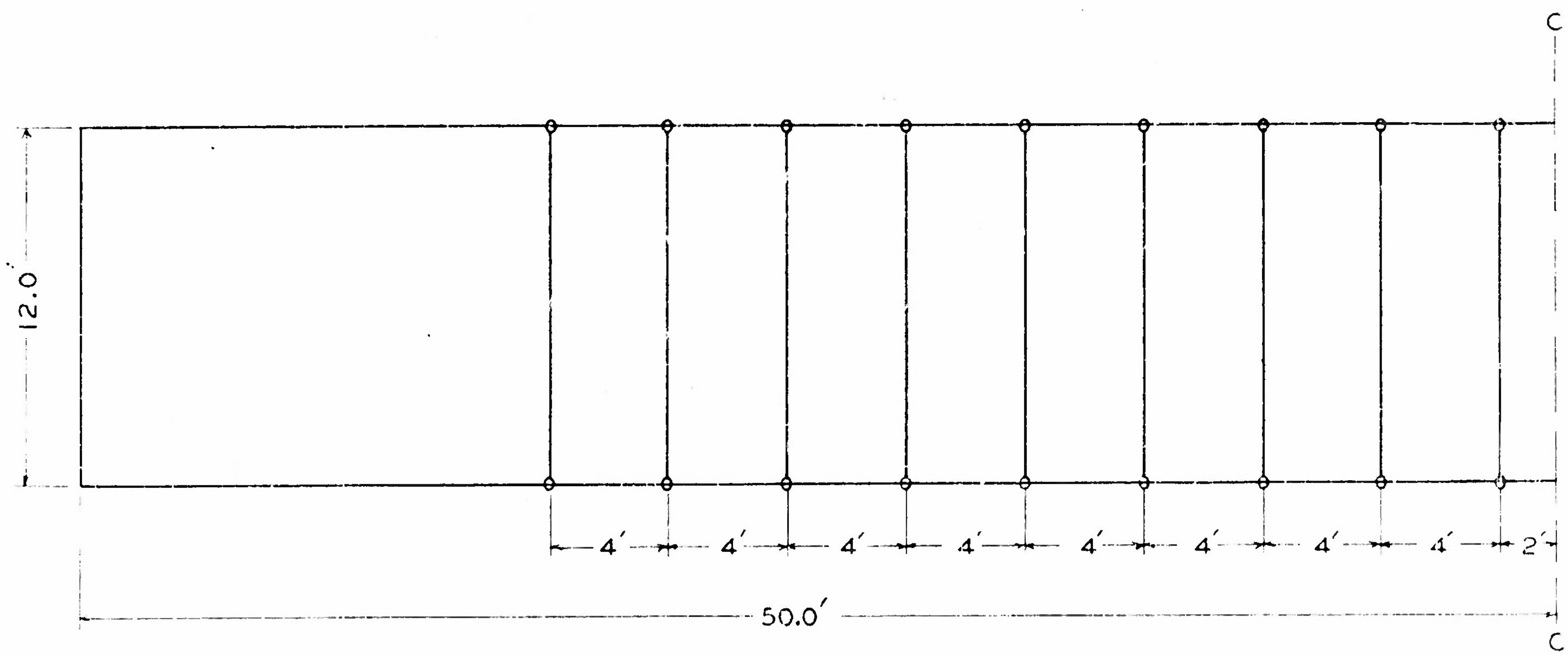
Barricade No. 13

It may well be that in stopping a plane with sweptback wings relatively few of the vertical elements will have to accept the major part of the retarding force. The simple barricade shown on page 100, or a modification thereof, may therefore be worth considering. In this barricade all vertical elements are free to slide along a common pair of longitudinal elements. As a plane engages the barricade the vertical elements on either side of the nose of the plane will be forced outward from the nose. Unless it is limited in some manner the separation of elements may well become so large that the plane can pass through. Friction along the leading edge of the wing will probably not provide sufficient limitation. The separation can be limited by flexible, longitudinal ties between those vertical elements a chosen distance apart.

The photographs on pages 101 and 102 illustrate the behavior of this barricade when engaging in a center landing and in a 16-foot off-center landing a plane with wings swept back 45°, assuming that the vertical elements do not slip along the leading edge of the wing. Corresponding data are given on page 103. The photographs on pages 104 and 105 illustrate the behavior of the barricade when engaging a plane with wings swept back 60° in a center landing and a 16-foot off-center landing. Corresponding data are shown on page 106.

Inspection of the tables on pages 103 and 106 shows that the forces in the two central elements of Barricade No. 13 are quite high. For a 16-foot off-center landing of a plane with wings swept back 60°, the maximum F/T is 1.10. This value is approximately twice the maximum F/T encountered in engaging with Barricade No. 10 a plane with straight wings in a 16-foot off-center landing. The maximum angle ϕ is approximately the same for either engagement. The torque on the plane is more favorable for an engagement of Barricade No. 13 with a plane with wings swept back 60° than for an engagement of No. 10 with a plane with straight wings.

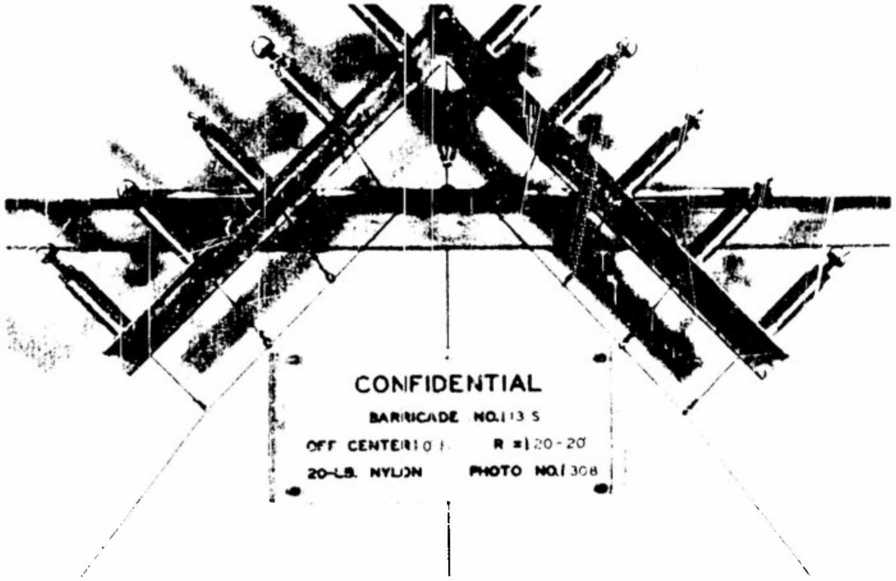
Limited separation of the central vertical elements upon impact of the plane would probably reduce the maximum angle ϕ. It could not improve appreciably the force distribution among the vertical elements. Any improvement in the maximum angle ϕ would therefore be accompanied by an increase in the maximum F/T. Although the force distribution might be improved, and hence the maximum value of F/T reduced, by employing vertical elements of different lengths, it is nevertheless felt that other designs will prove more satisfactory than No. 13.

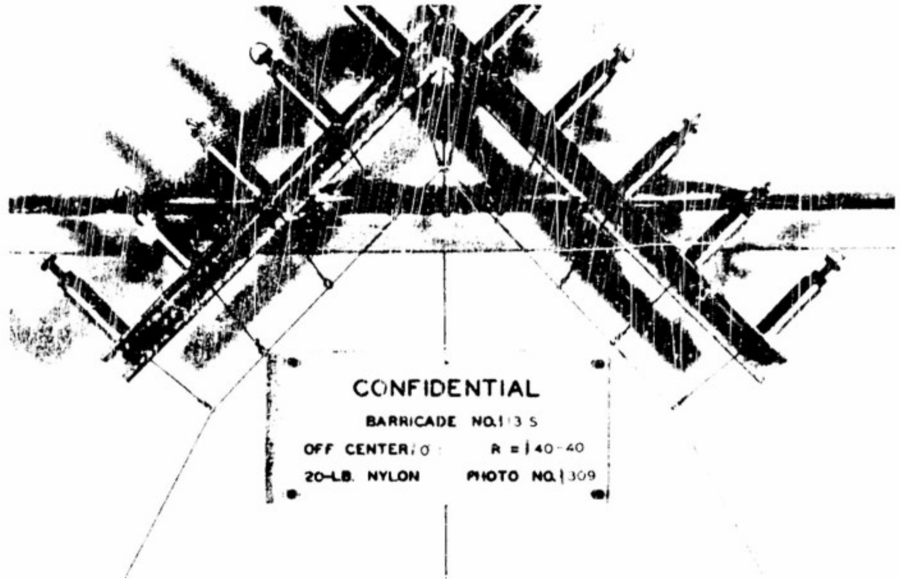


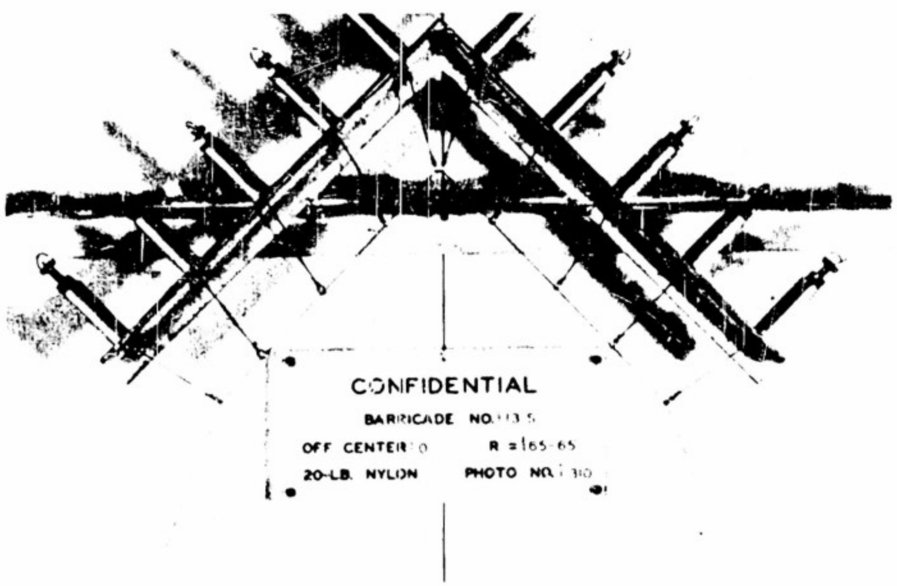
BARRICADE NO. 13 DESIGN

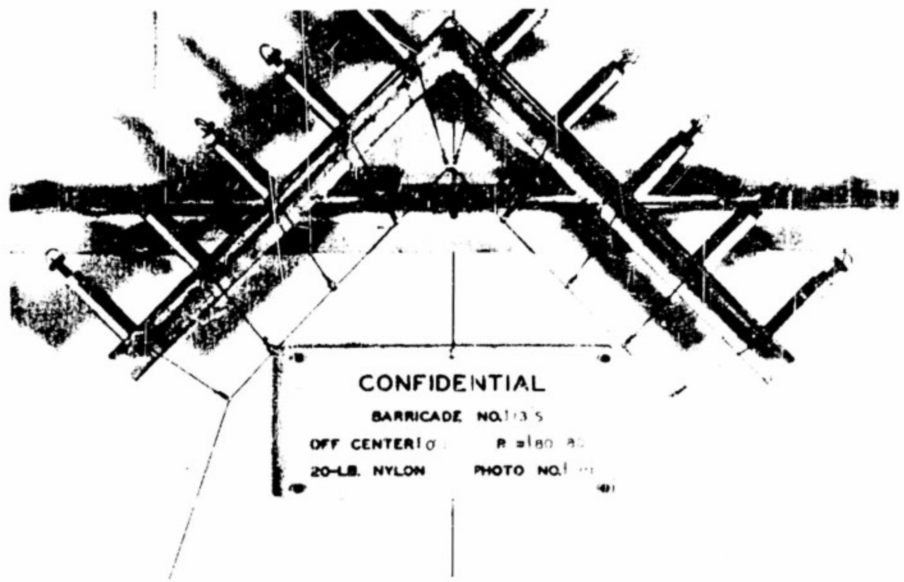
SCALE 3/16" = 1'

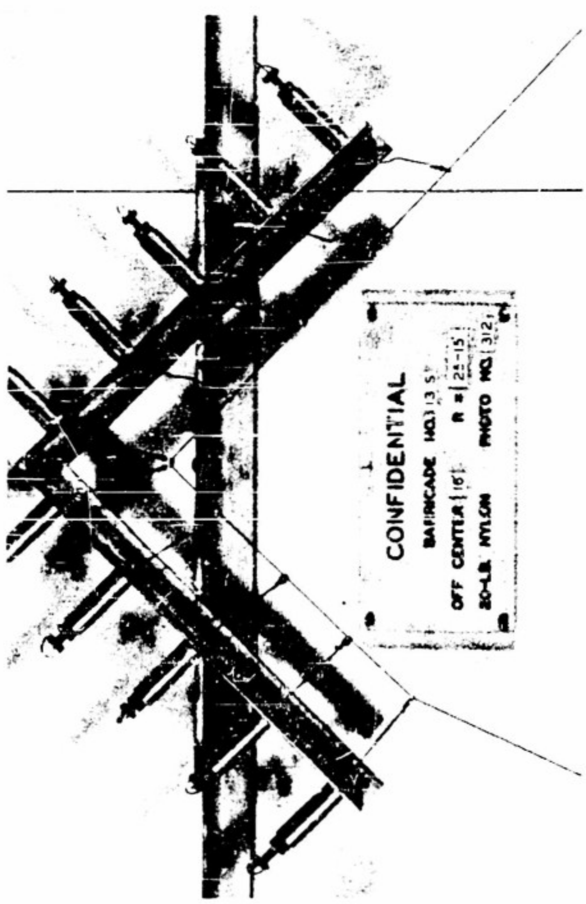
CONFIDENTIAL

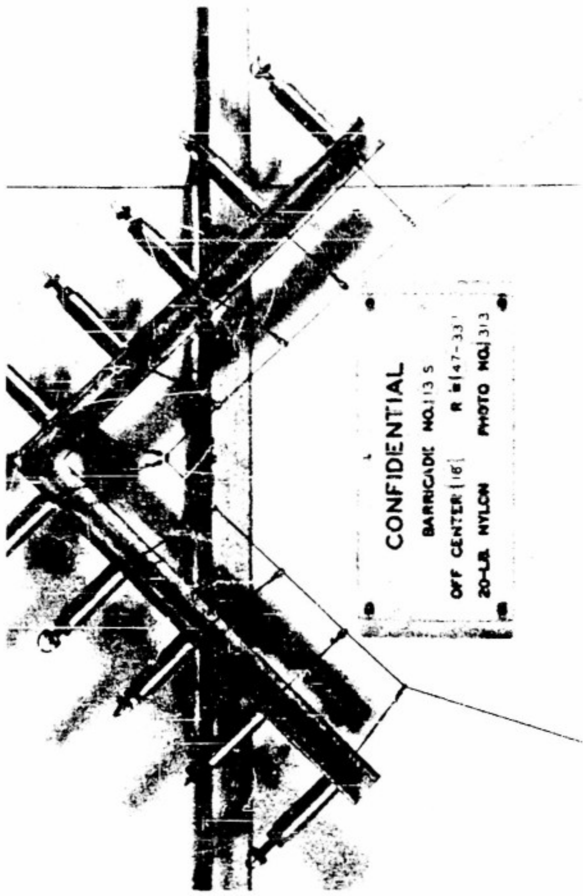

CONFIDENTIAL
BARRICADE NO.113 S
OFF CENTER 0
R = 120-20
20-LB. NYLON
PHOTO NO.1308

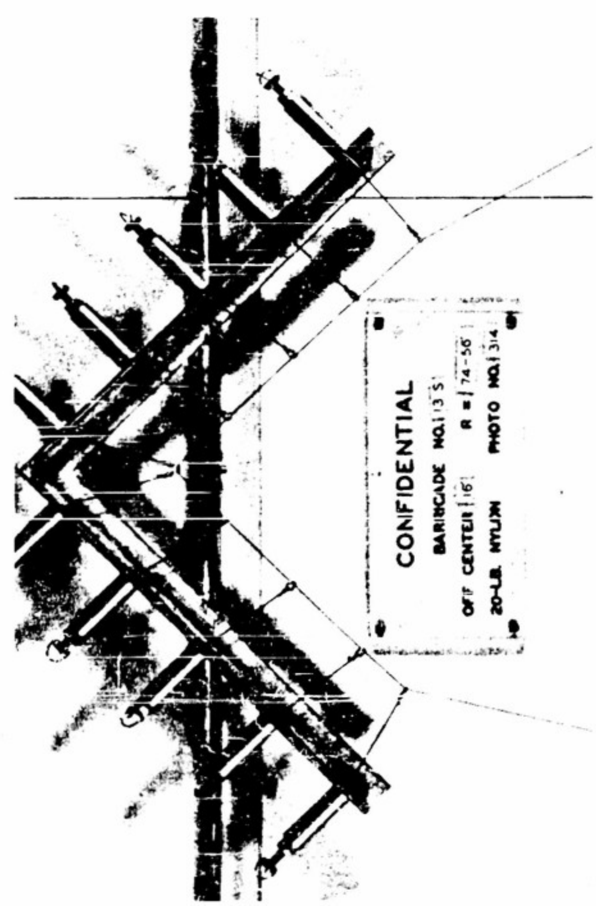

CONFIDENTIAL
BARRICADE NO.113 S
OFF CENTER 0
R = 140-40
20-LB. NYLON
PHOTO NO.1309

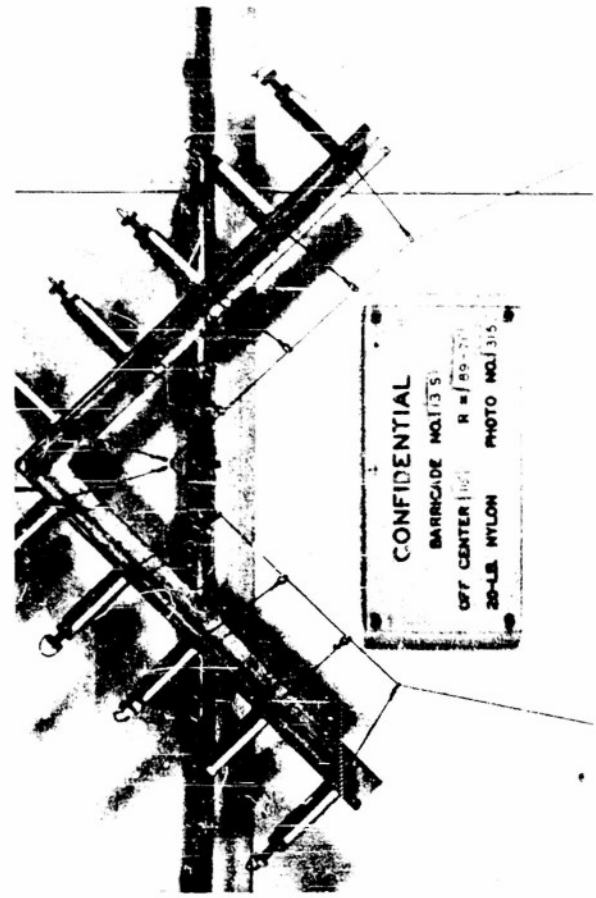

CONFIDENTIAL
BARRICADE NO.113 S
OFF CENTER 0
R = 165-65
20-LB. NYLON
PHOTO NO.1310


CONFIDENTIAL
BARRICADE NO.113 S
OFF CENTER 0
20-LB. NYLON
PHOTO NO.


CONFIDENTIAL
BARRICADE NO. 13 S
OFF CENTER 16' R = 21-15'
20-LB. NYLON PHOTO NO. 312


CONFIDENTIAL
BARRICADE NO. 13 S
OFF CENTER 16' R = 47-33'
20-LB. NYLON PHOTO NO. 313


CONFIDENTIAL
BARRICADE NO. 13 S
OFF CENTER 16' R = 74-56'
20-LB. NYLON PHOTO NO. 314


CONFIDENTIAL
BARRICADE NO. 13 S
OFF CENTER
R = 89-7
20-LB. NYLON PHOTO NO. 315

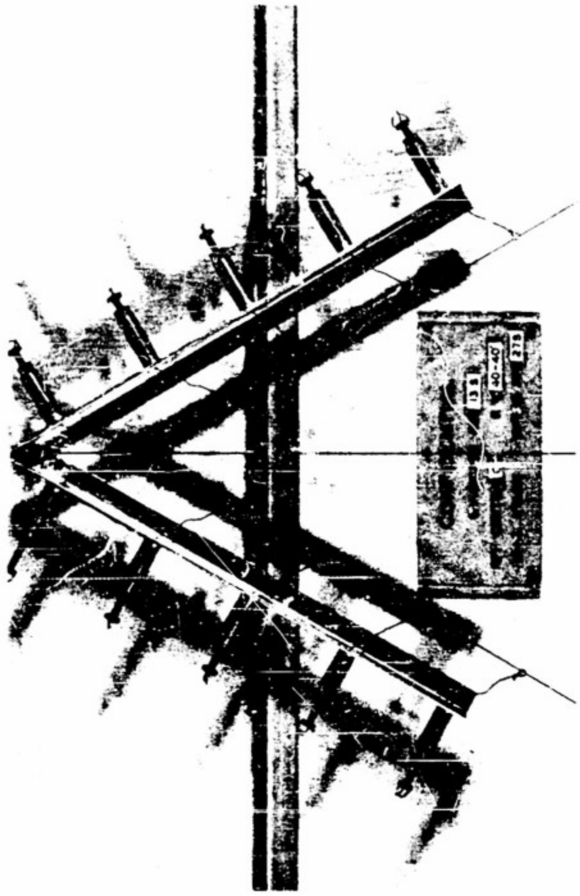
Barricade No. 13 S

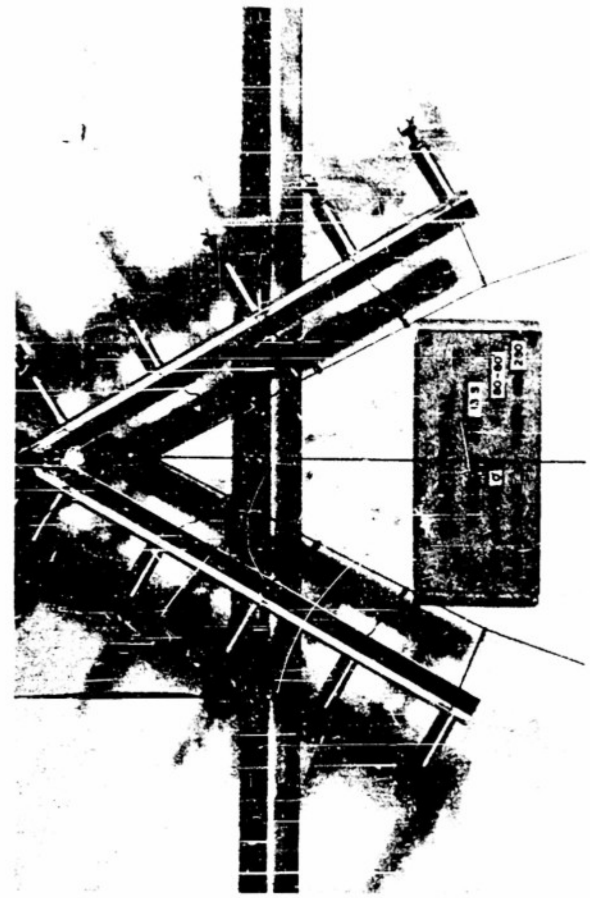
Plane Wings Swept Back 45°

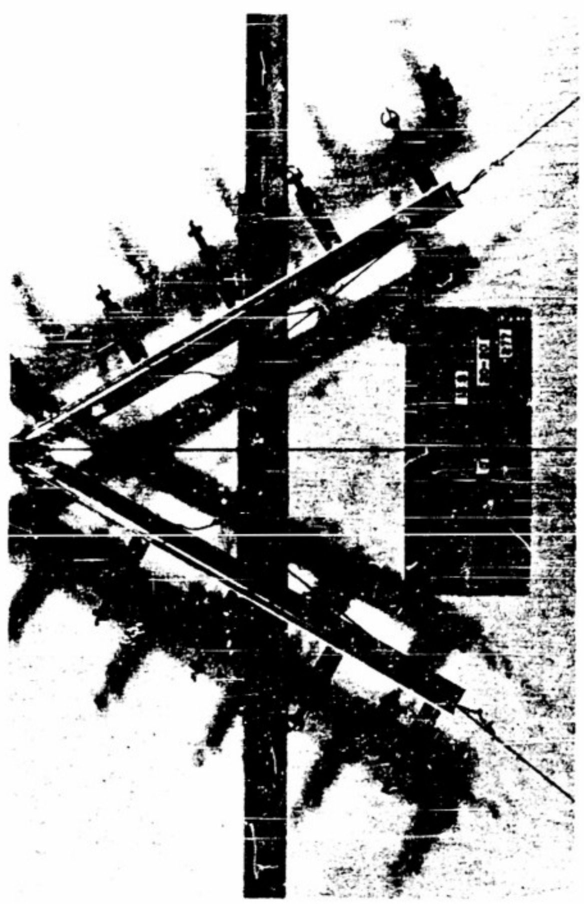
Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

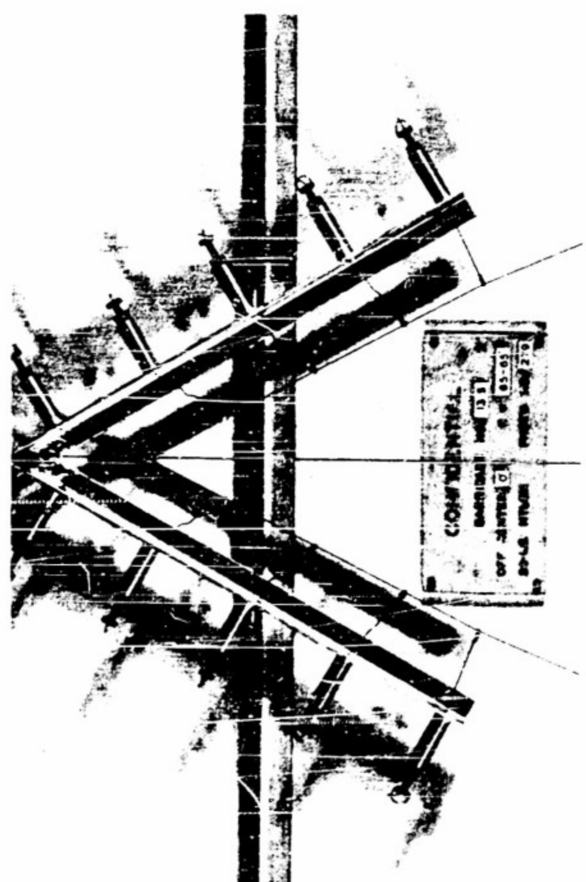
	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	25-15	47-33	74-56	89-71
Photo No.	308	309	310	311	312	313	314	315
F_1/T	.11	.21	.30	.38	.30	.40	.45	.50
F_2/T	0	0	0	0	0	.01	.02	.03
F_3/T	0	0	0	0	0	0	0	0
F_4/T	0	0	0	0	0	0	0	0
F_5/T	.76	.76	.77	.76	.76	.73	.71	.73
F_6/T	.76	.76	.77	.76	.72	.80	.82	.79
F_7/T	0	0	0	0	0	0	0	0
F_8/T	0	0	0	0	0	0	0	0
F_9/T	0	0	0	0	0	0	0	0
F_{10}/T	.11	.21	.30	.38	0	.08	.21	.24
Max. ϕ	29°	29°	29°	29°	28°	29°	29°	29°
Element	#5	#5	#5	#5	#6	#6	#6	#6

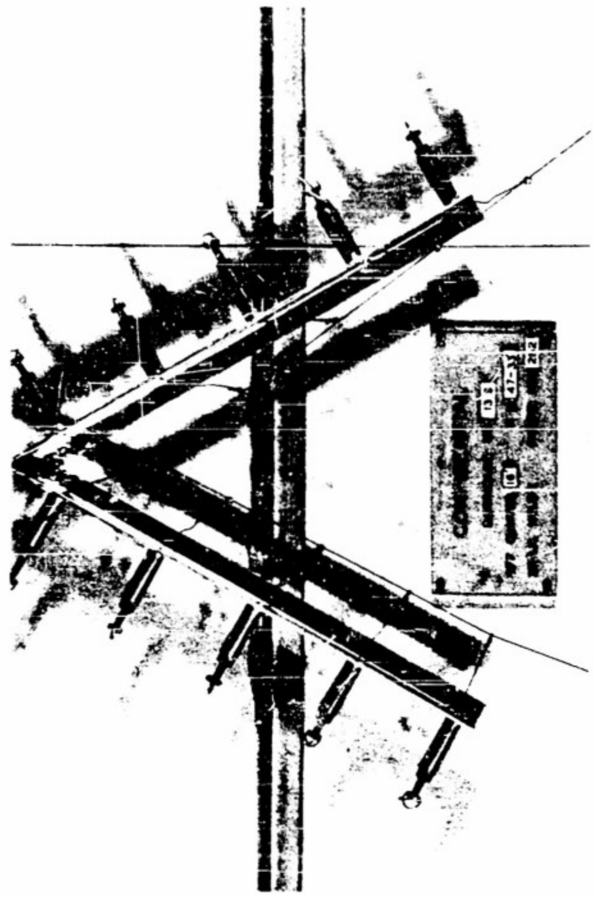
	On Center	16 ft. Off Center
Maximum F/T at any runout	0.76	0.82
Maximum angle ϕ at any runout	29°	29°
F_o/T at 40-foot runout	0	0.38
F_o/T at 80-foot runout	0	0.46
Torque/T at 40-foot runout	0	-6.2 ft.
Torque/T at 80-foot runout	0	-9.6 ft.

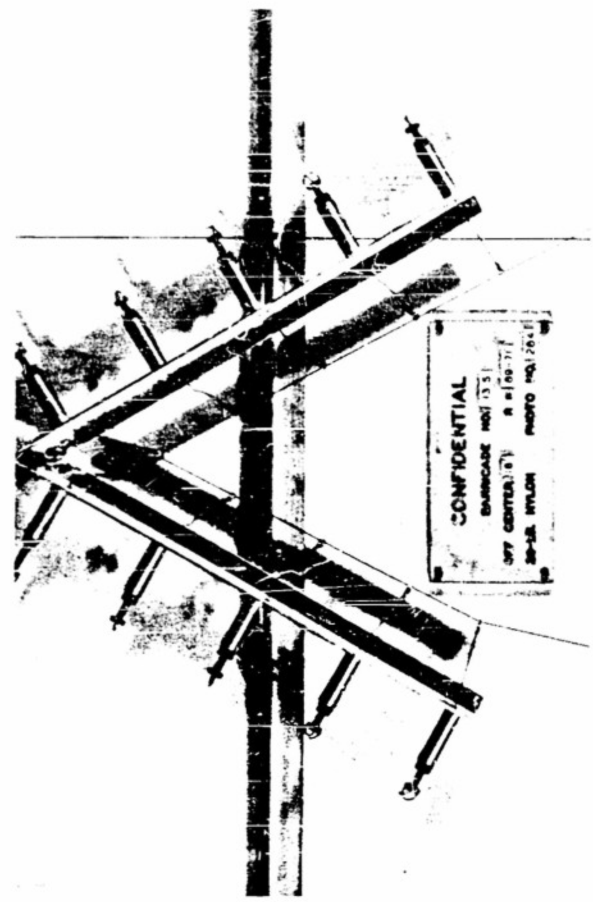


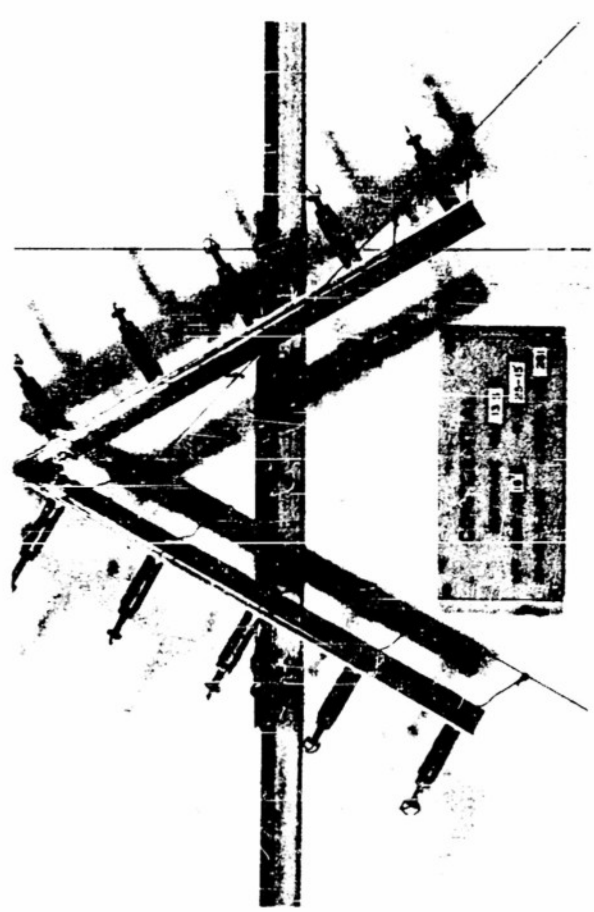


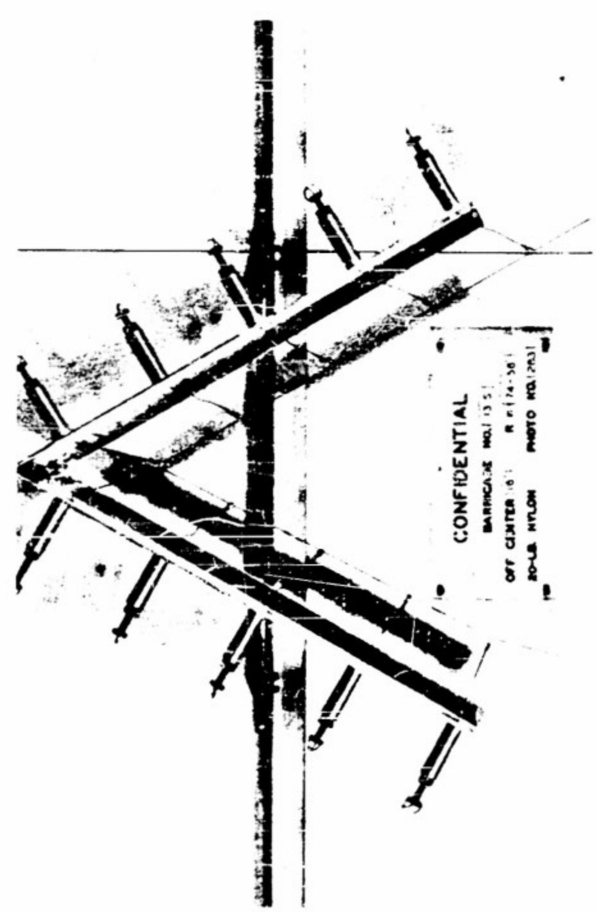







CONFIDENTIAL
BARRICADE NO.
OFF CENTER
20-LB. NYLON PHOTO NO.




CONFIDENTIAL
BARRICADE NO.
OFF CENTER
20-LB. NYLON PHOTO NO.

Barricade No. 13 S

Plane Wings Swept Back 60°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	25-15	47-33	74-56	89-71
Photo No.	277	278	279	280	281	282	283	284
F_1/T	0	0	.07	.16	0	.11	.21	.24
F_2/T	0	0	0	0	0	0	0	0
F_3/T	0	0	0	0	0	0	0	0
F_4/T	0	0	0	0	0	0	0	0
F_5/T	.85	.90	.92	.92	1.10	.99	.86	.92
F_6/T	.84	.91	.92	.92	.56	.77	.98	.92
F_7/T	0	0	0	0	0	0	0	0
F_8/T	0	0	0	0	0	0	0	0
F_9/T	0	0	0	0	0	0	0	0
F_{10}/T	0	0	.07	.16	0	0	0	.01
Max. ϕ	45°	44°	45°	44°	47°	47°	47°	45°
Element	#5	#5	#5	#5	#6	#6	#6	#5

	On Center	16 ft. Off Center
Maximum F/T at any runout	0.92	1.10
Maximum angle ϕ at any runout	45°	47°
F_c/T at 40-foot runout	0	0.28
F_c/T at 80-foot runout	0	0.23
Torque/T at 40-foot runout	0	0.27 ft.
Torque/T at 80-foot runout	0	-3.2 ft.

Barricade No. 15

Largely because the included angle between the leading edges of wings having a sweepback of 45° has the particular value of 90°, such a plane lends itself to a design of barricade which will distribute the forces moderately well and at the same time keep the angle ϕ small. Barricade No. 15, illustrated on page 109, represents such a design. Let it be assumed that one desires that the two vertical elements of a given loop be 20 feet apart. If a rectangular loop of this length is 8.28 feet high, the dimensions are such that when folded over thin wings the collapsed loop will complete a rectangle of which the leading edges of the wings form two sides and the folded loop the other two sides. (See photographs on page 110.) Five such rectangular loops engage the wings. Each of these loops is connected by two rings to a different pair of longitudinal elements. Both the loops and the longitudinal elements are free to slide through the rings. In principle each fifth loop can be connected to the same pair of longitudinal elements, though the loops may not be sufficiently long when folded to avoid interference from those loops of which the plane engages only one of the two vertical elements. Such interference can be avoided by using more than 5 pairs of longitudinal elements, say by using 7 pairs and connecting each seventh loop to a common pair.

The photographs on pages 110 and 111 show the behavior of the barricade for a center landing and a 16-foot off-center landing respectively, the arresting engine being singly reeved in each case. The corresponding tabular data are shown on pages 113 and 114. The photographs on page 112 compare the behavior for landings 0, 8, 16 and 24 feet off center, all at a runout of 40 feet and all for a singly reeved arresting engine. The corresponding tabular data are shown on page 115.

The following comments will aid in evaluating the merits of this barricade for an engagement with wings swept back 45°:

1. To the extent that one is concerned with the forces in the vertical elements, the angles at which these forces act, the component of force toward the center line of the deck, and the torque exerted on the plane, Barricade No. 15 is as satisfactory for stopping a 45° sweptback wing plane as No. 10 is for stopping a straight wing plane. Comparison of the tables on pages 114 and 49, each for a 16-foot off-center landing, shows that:

   a. The maximum F/T is 0.54 for No. 15 whereas it was 0.47 for No. 10.

   b. The maximum angle ϕ is 22° for No. 15 whereas it was 40° for No. 10.

   c. F_o/T at 40-foot runout is 0.25 for No. 15 whereas it was 0.32 for No. 10.

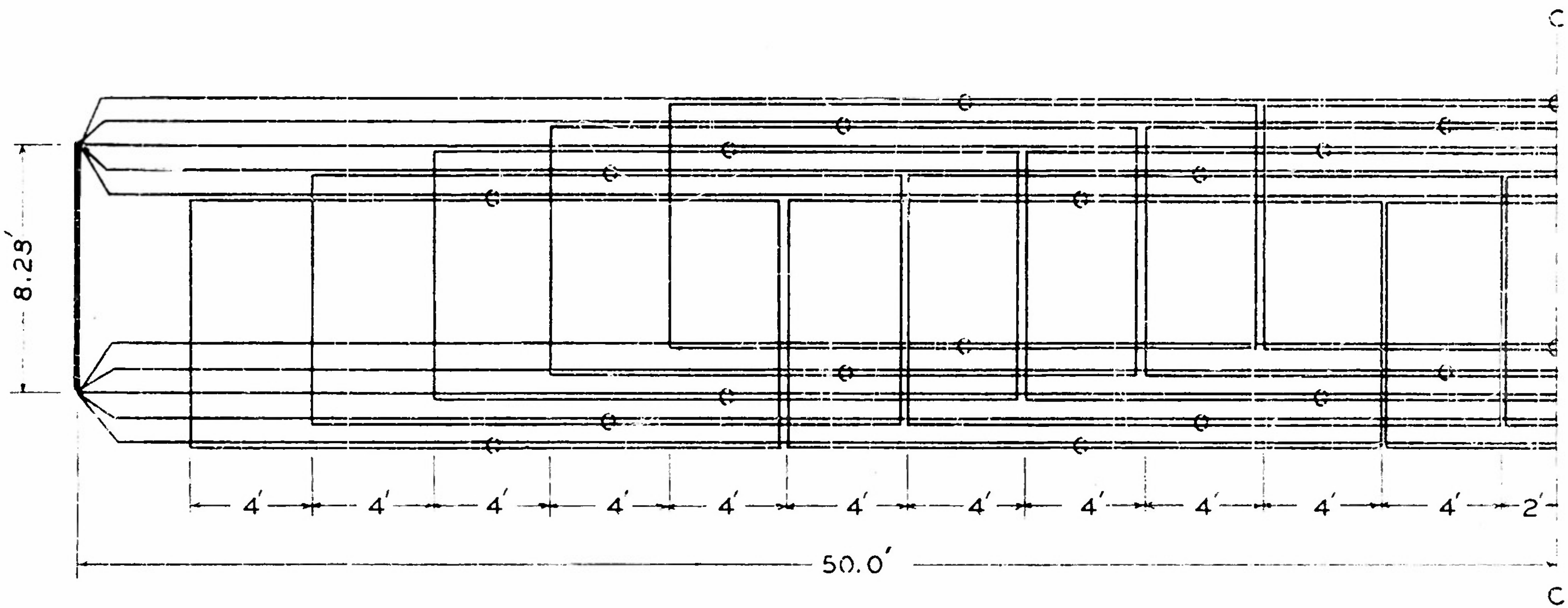
   d. Torque/T at a 40-foot runout is -6.1 ft. for No. 15 whereas it was -7.3 ft. for No. 10.

2. The tendency of the impact of the plane to push centrally located vertical elements farther from the center will no doubt result in an actual behavior which differs considerably from the behavior indicated here. As pointed out previously, a limited tendency in this direction would result in an actual improvement. The length of a rectangular loop when in the folded position would probably prevent this tendency becoming so great as to render the barricade useless.

3. Barricade No. 15 would be far from satisfactory for engaging a plane with wings swept back 60°. A somewhat similar design, No. 21, however, is about as satisfactory for a 60° sweepback as No. 15 is for a 45° sweepback.

4. Barricade No. 15 has two disadvantages. One is that some of the longitudinal elements must move across the tail fin as the engagement takes place, thus providing an excellent chance of undesirable entanglement with the fin. The next barricade discussed, No. 20, represents a modification which will reduce but not eliminate the possibility of such entanglement.

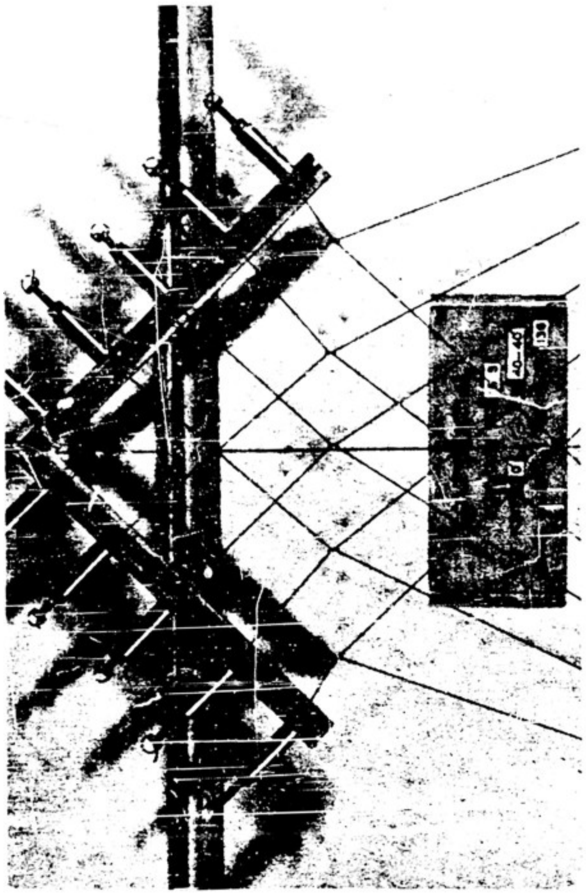
5. Barricade No. 15 also suffers from the fact that its behavior upon engaging a plane making a skew landing, or a landing in which the plane's velocity is not parallel to the center line of the deck (fuselage parallel to velocity), is quite different from its behavior upon engaging a plane the fuselage of which is parallel to the center line of the deck. It is true that the modified force distribution for a skew landing is such as to right the plane. However, relatively large tensions will exist in those vertical elements which form a part of that loop connected to the horizontal element farthest to that side on which the plane wing is most forward in the skew landing.

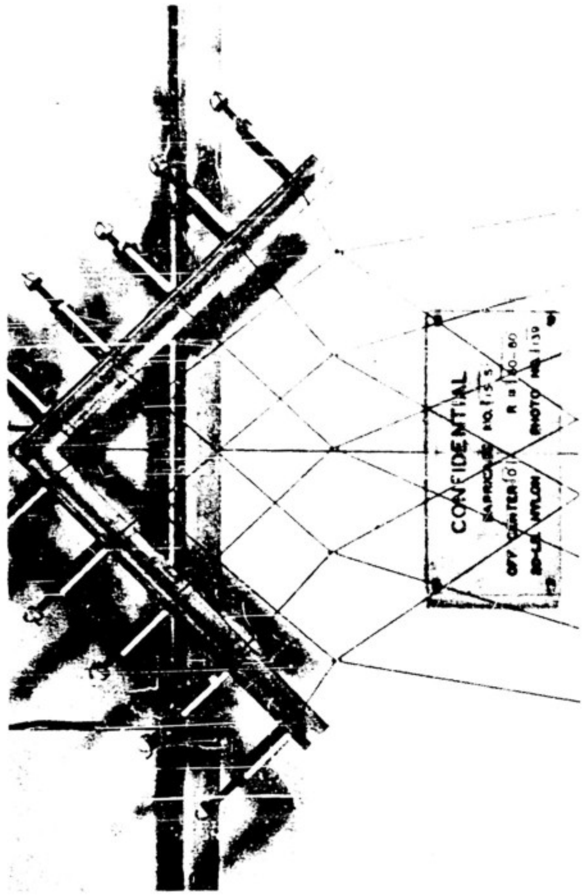


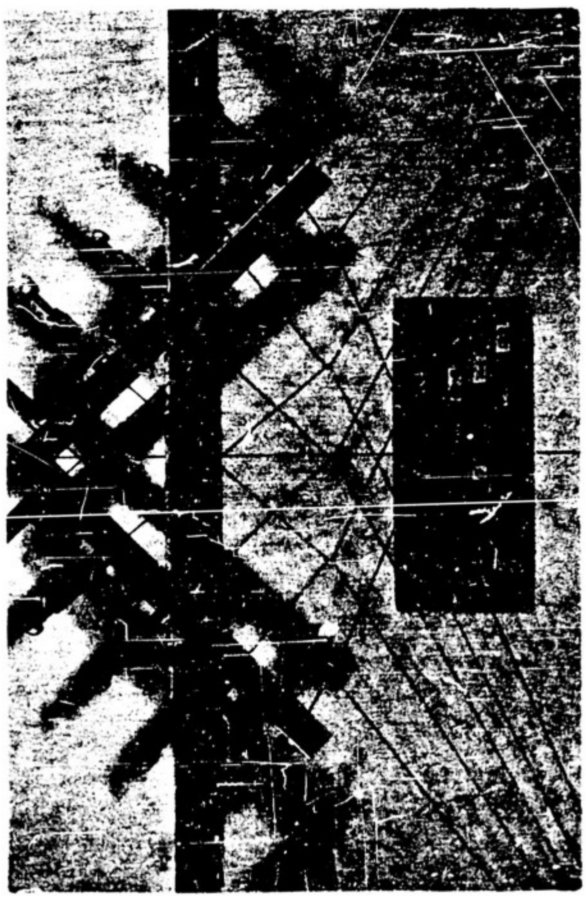
BARRICADE NO. 15 DESIGN

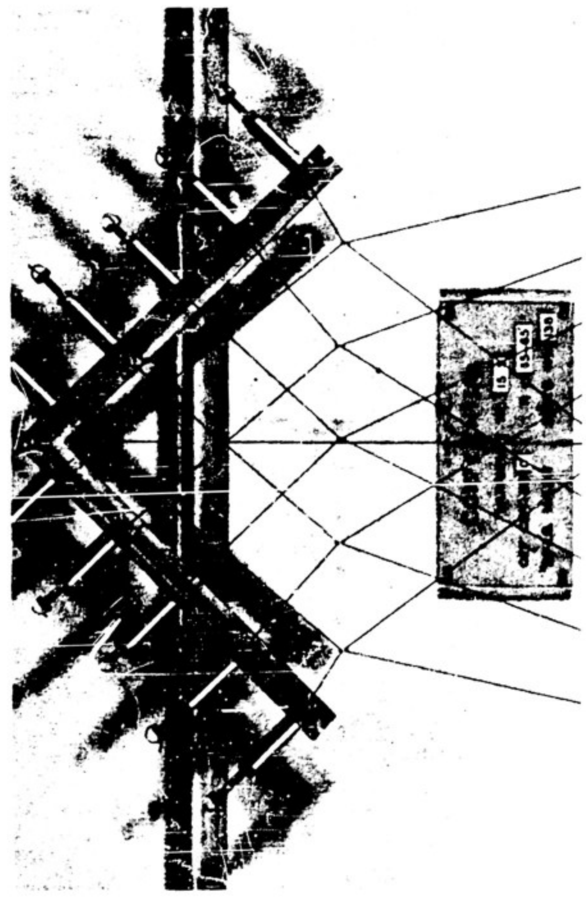
SCALE 3/16" = 1'

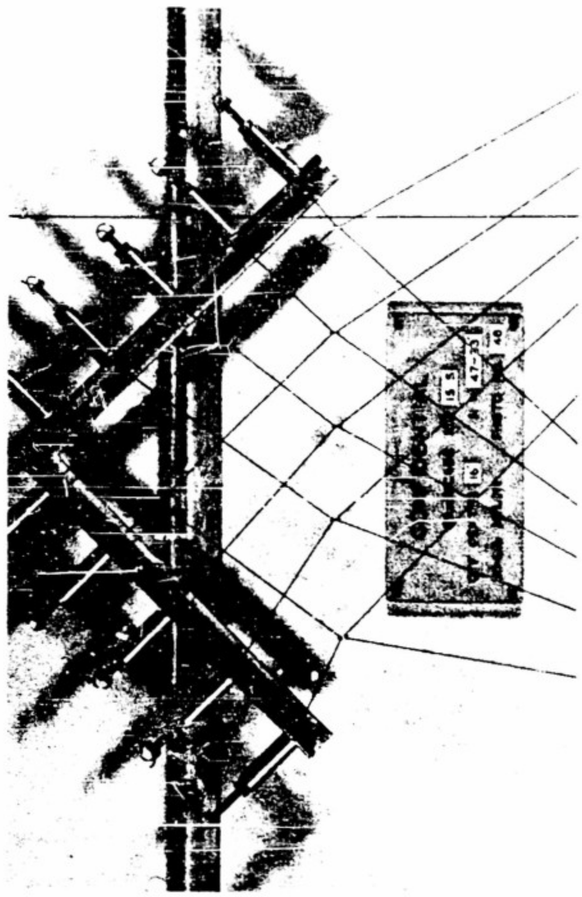
CONFIDENTIAL

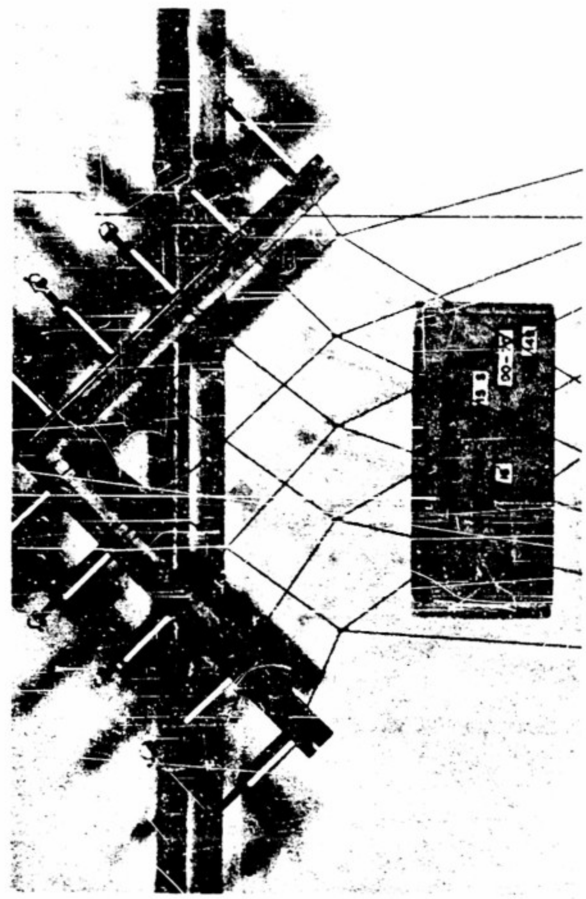


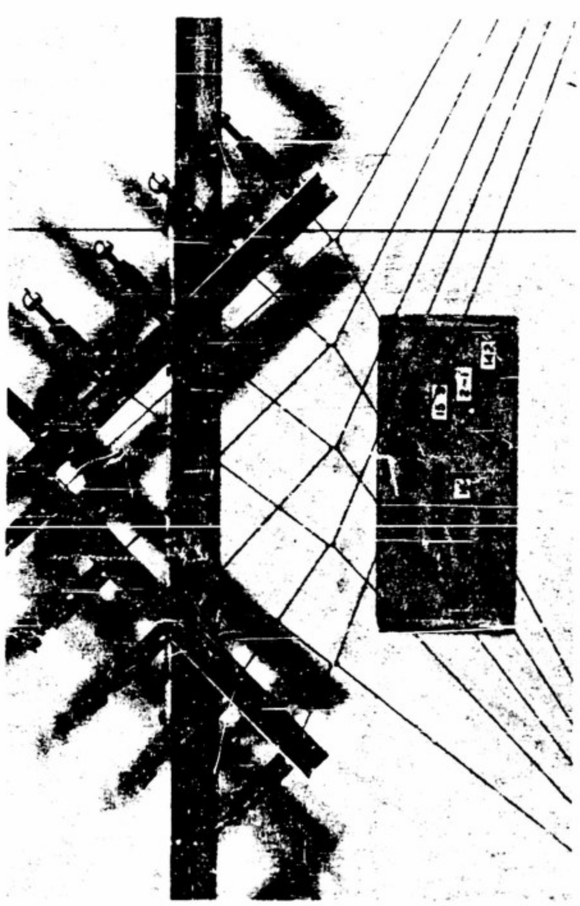

CONFIDENTIAL

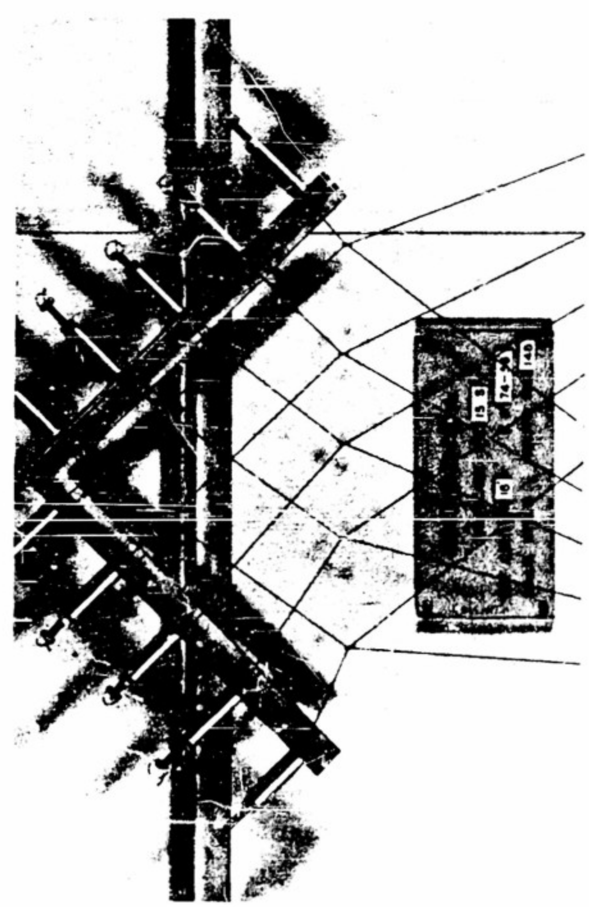


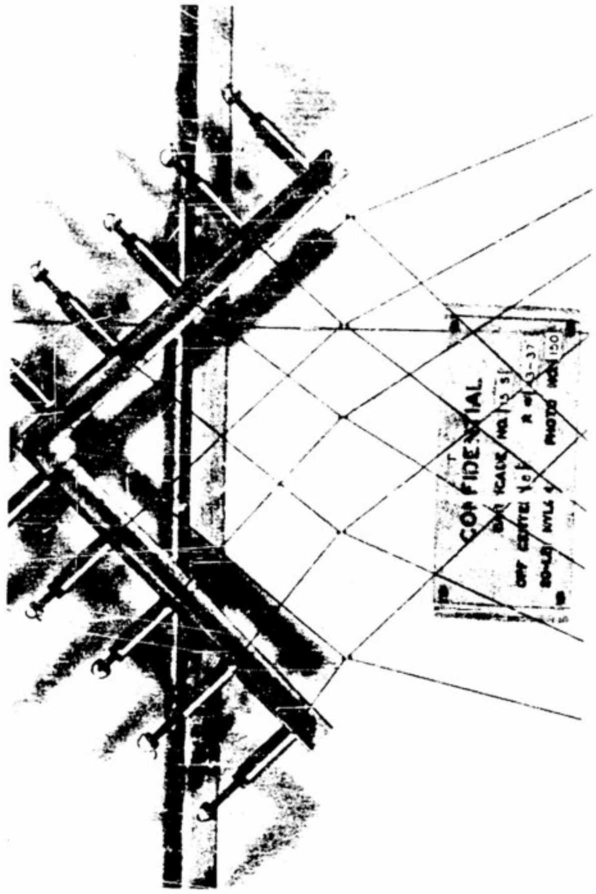


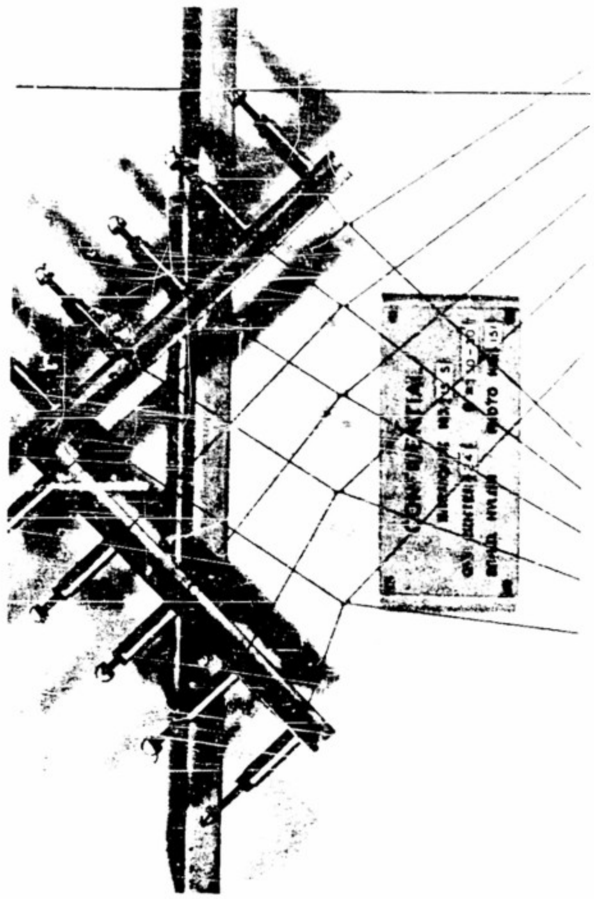


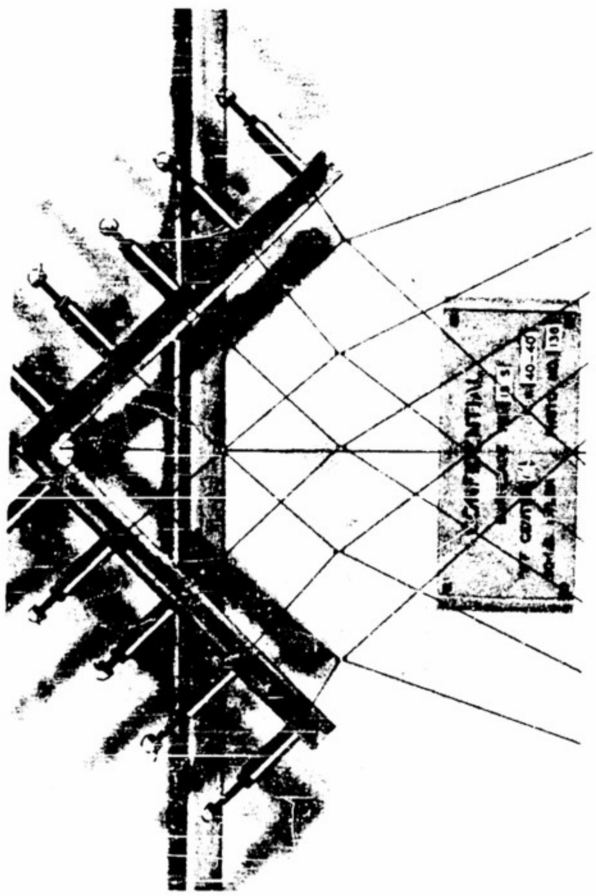


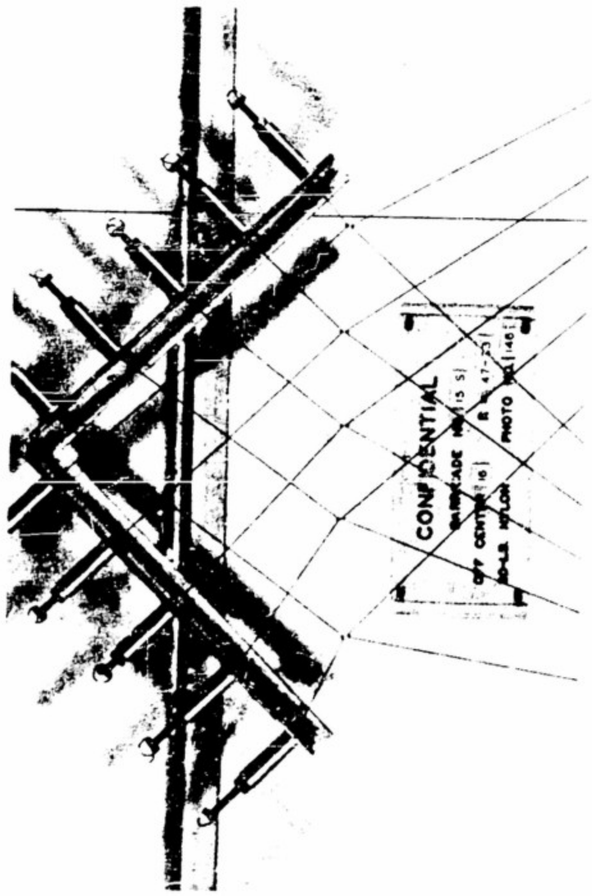












Barricade No. 15 S (or D)

Plane Wings Swept Back 45°

Singly Reeved (or Doubly Reeved)
Center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	1-1	10-10	20-20	30-30	40-40	50-50	65-65	80-80
Photo No.	132	133	134	135	136	137	138	139
F_1/T	.15	.25	.29	.33	.33	.35	.36	.38
F_2/T	.12	.15	.19	.19	.19	.20	.21	.23
F_3/T	.11	.12	.13	.14	.13	.15	.16	.17
F_4/T	.12	.15	.18	.19	.19	.20	.21	.23
F_5/T	.15	.24	.28	.33	.32	.35	.36	.38
F_6/T	.15	.24	.28	.33	.32	.35	.36	.38
F_7/T	.12	.15	.18	.19	.19	.20	.21	.23
F_8/T	.11	.12	.13	.14	.13	.15	.16	.17
F_9/T	.12	.15	.19	.19	.19	.20	.21	.23
F_{10}/T	.15	.25	.29	.33	.33	.35	.36	.38
Max. ϕ	16°	11°	11°	10°	14°	15°	13°	13°
Element	#1	#1	#1	#1	#1	#1	#1	#1

Maximum F/T at any runout = 0.38

Maximum angle ϕ at any runout = 16°

F_o/T at 40-foot runout = 0

F_o/T at 80-foot runout = 0

Torque/T at 40-foot runout = 0

Torque/T at 80-foot runout = 0

Barricade No. 15 S

Plane Wings Swept Back 45°

Singly Reeved
16-ft. Off-center Landing
Barricade of 20-lb. Nylon
T = 2000 grams

R	2-1	13-7	25-15	36-24	47-33	58-42	74-56	90-70
Photo No.	142	143	144	145	146	147	148	149
F_1/T	.29	.47	.52	.52	.52	.53	.54	.54
F_2/T	.20	.25	.27	.28	.28	.28	.28	.28
F_3/T	.14	.14	.15	.15	.15	.16	.16	.17
F_4/T	.10	.10	.11	.12	.12	.13	.15	.16
F_5/T	.05	.06	.09	.12	.13	.16	.19	.22
F_6/T	.29	.45	.51	.52	.52	.53	.54	.54
F_7/T	.20	.25	.27	.28	.28	.28	.28	.28
F_8/T	.14	.14	.15	.15	.15	.16	.16	.17
F_9/T	.10	.10	.11	.12	.12	.13	.15	.16
F_{10}/T	.05	.06	.09	.12	.13	.16	.19	.22
Max. ϕ	23°	21°	21°	20°	20°	22°	22°	22°
Element	#1	#1	#1	#1	#1	#1	#1	#1

Maximum F/T at any runout = 0.54

Maximum angle ϕ at any runout = 22°

F_c/T at 40-foot runout = 0.25

F_c/T at 80-foot runout = 0.26

Torque/T at 40-foot runout = -6.1 ft.

Torque/T at 80-foot runout = -3.8 ft.

Barricade No. 15 S

Plane Wings Swept Back 45°

Singly Reeved
Amount Off-center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

Off Center	0	8	16	24
R	40-40	43-37	47-33	50-30
Photo No.	136	150	146	151
F_1/T	.33	.38	.52	.66
F_2/T	.19	.22	.28	.29
F_3/T	.13	.15	.15	.14
F_4/T	.19	.16	.12	.07
F_5/T	.32	.24	.13	.06
F_6/T	.32	.37	.52	.65
F_7/T	.19	.22	.28	.29
F_8/T	.13	.15	.15	.14
F_9/T	.19	.16	.12	.07
F_{10}/T	.33	.24	.13	.06
Max. ϕ	14°	11°	20°	27°
Element	#1	#1	#1	#1

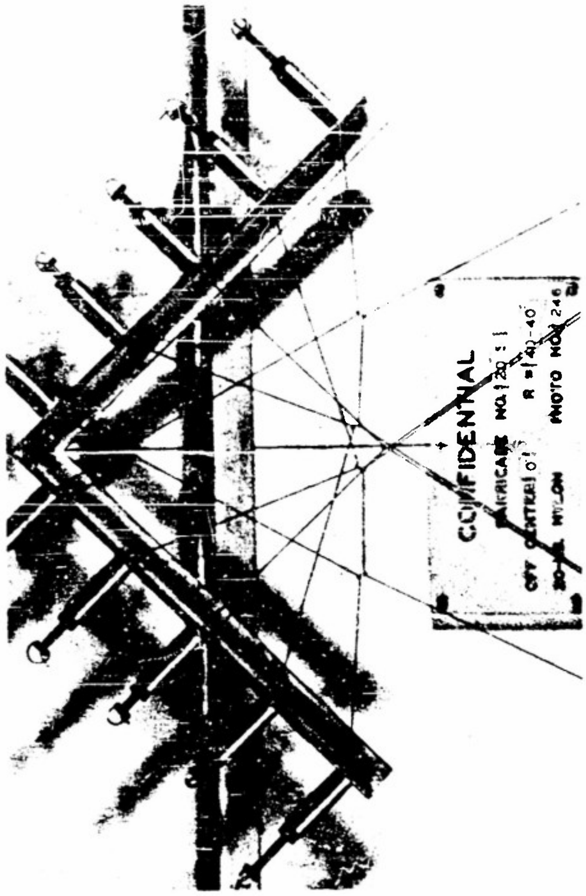
Off Center	0	8	16	24
Maximum F/T at 40-foot runout	0.33	0.38	0.52	0.66
Maximum angle ϕ at 40-foot runout	14°	11°	20°	27°
F_c/T at 40-foot runout	0	0.14	0.25	0.43
Torque/T at 40-foot runout	0	-1.9 ft.	-6.1 ft.	-8.7 ft.

Barricade No. 20

Barricade No. 20 is of the same design as No. 15 except for one feature. Whereas in No. 15 each fifth rectangular loop was connected by rings to a common pair of longitudinal elements, in No. 20 each third rectangular loop is connected to a common pair. (See photographs on page 117.) Thus, in engaging a plane with wings swept back 45°, only three pairs of longitudinal elements of No. 20 are operative; there were five pairs operative during an engagement with No. 15. That rectangular loop centrally located with respect to the plane is the only loop acting on one pair of longitudinal elements. On each other pair there are two loops acting, one to the port and one to the starboard side of the central loop. This feature reduces the tendency for the longitudinal elements to move across the tail fin as the plane proceeds after initial engagement. It also leads to a much more favorable force distribution upon engaging a plane in a skew landing.

The series of photographs on pages 117 and 118 illustrate respectively the behavior of Barricade No. 20 when engaging in a center landing and a 16-foot off-center landing a plane with wings swept back 45°. The corresponding tabular data are shown on page 119.

The distribution of forces is as satisfactory for this barricade as it was for No. 15. There is much less chance of entanglement of this barricade with the tail fin than there was for No. 15. Even so, certain elements of this barricade still operate so close to the tail fin that interference is still possible. Unlike the situation which existed for No. 15, the force distribution in Barricade No. 20 would not be greatly different for a landing in which the fuselage is not parallel to the center line of the deck than it is for a landing in which the fuselage is parallel to the center line.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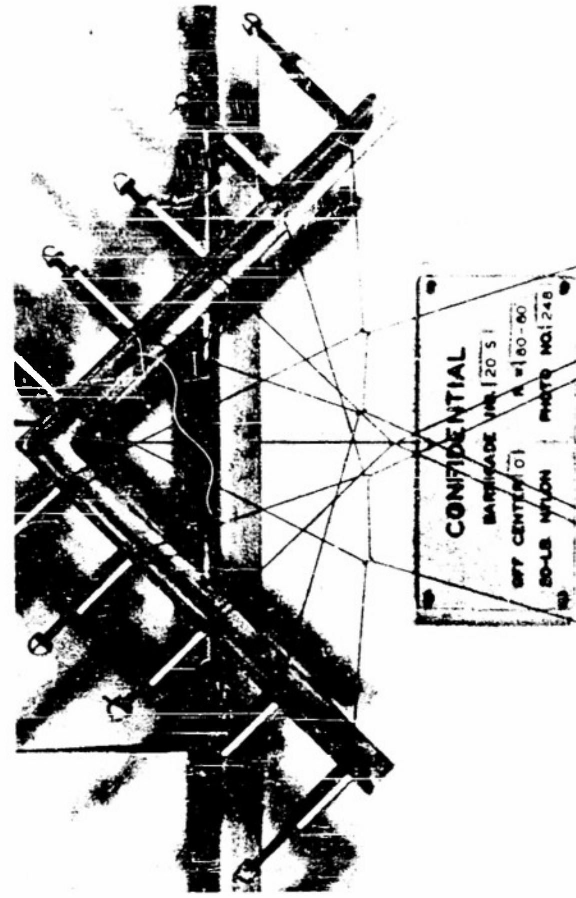
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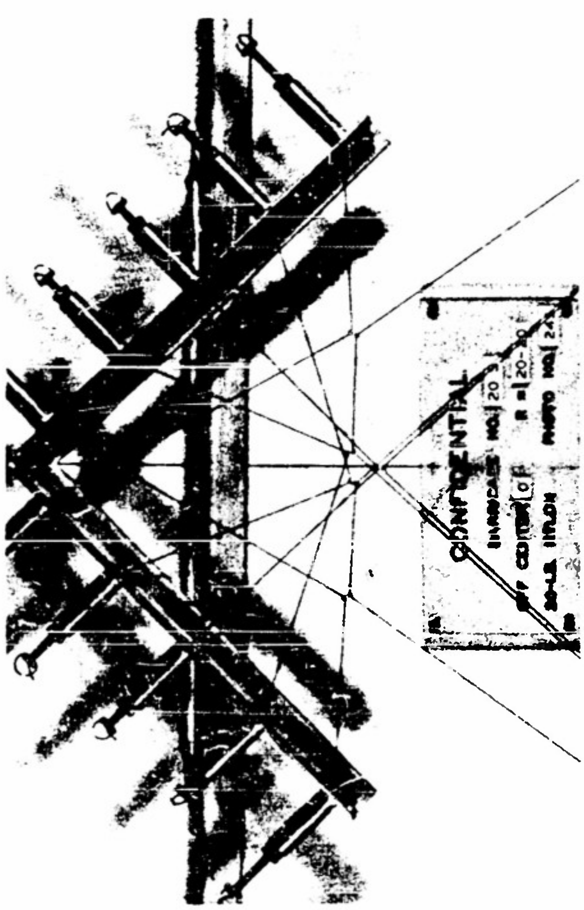
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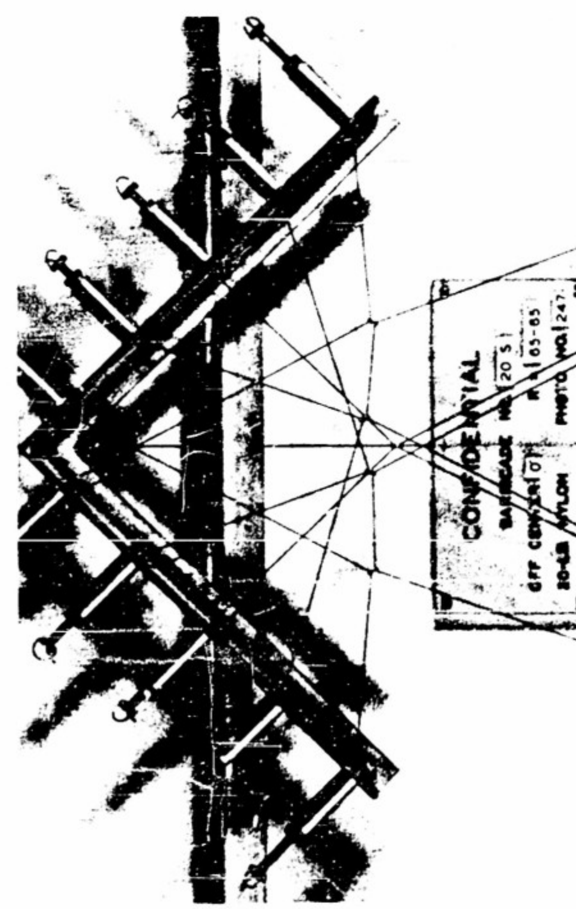
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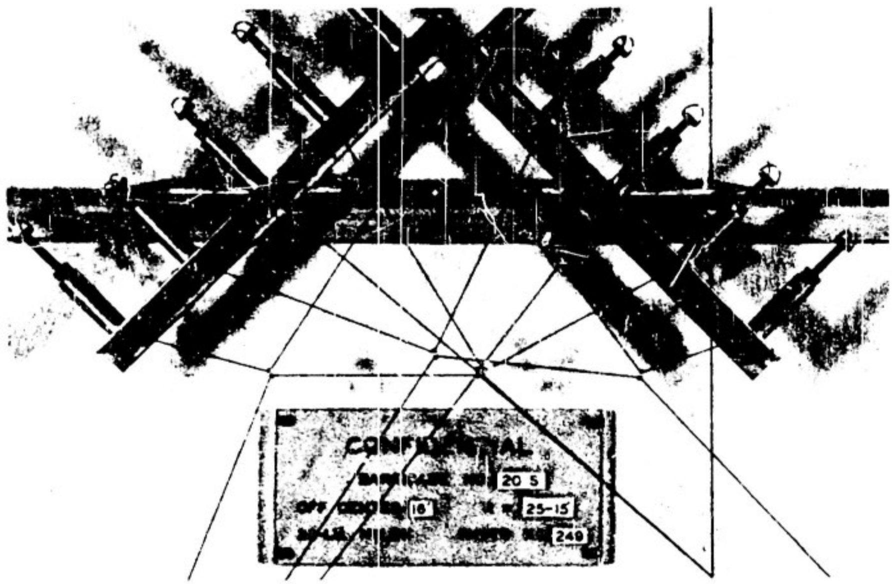
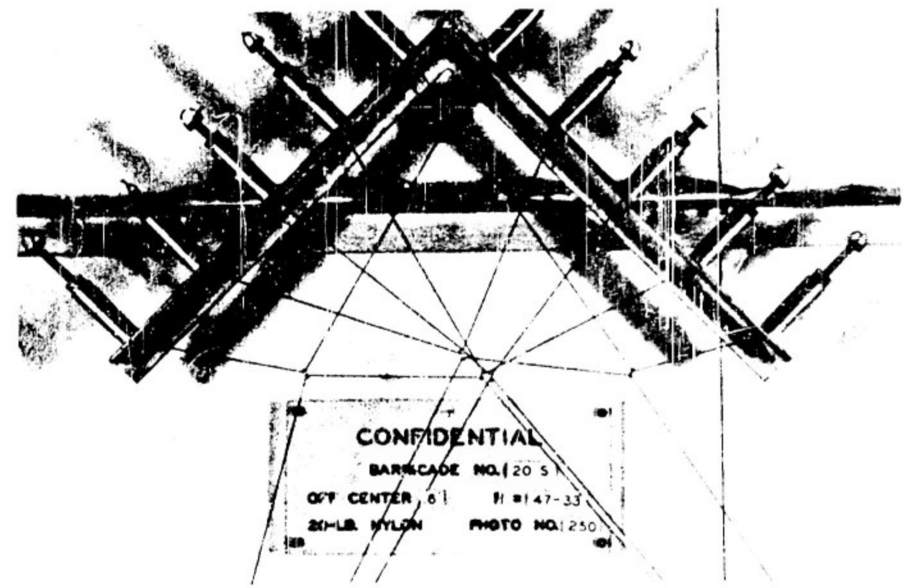
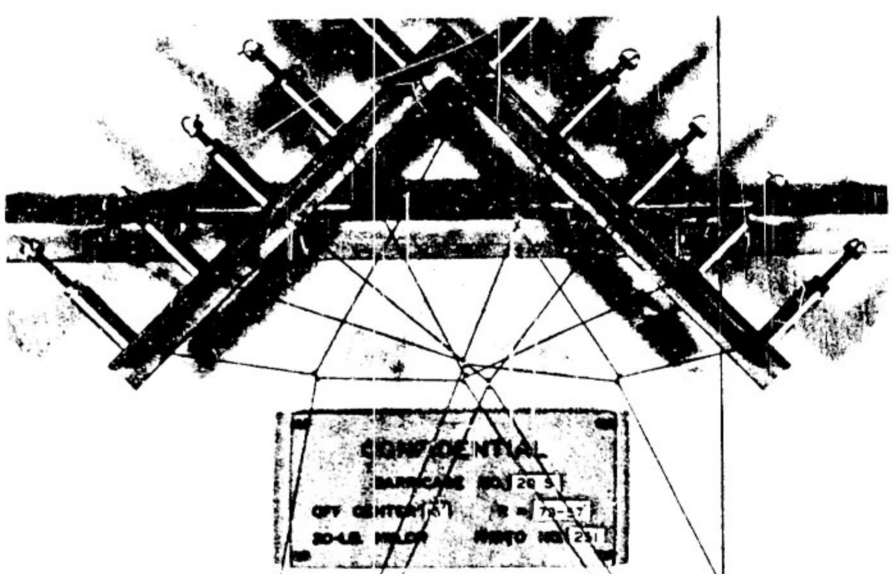
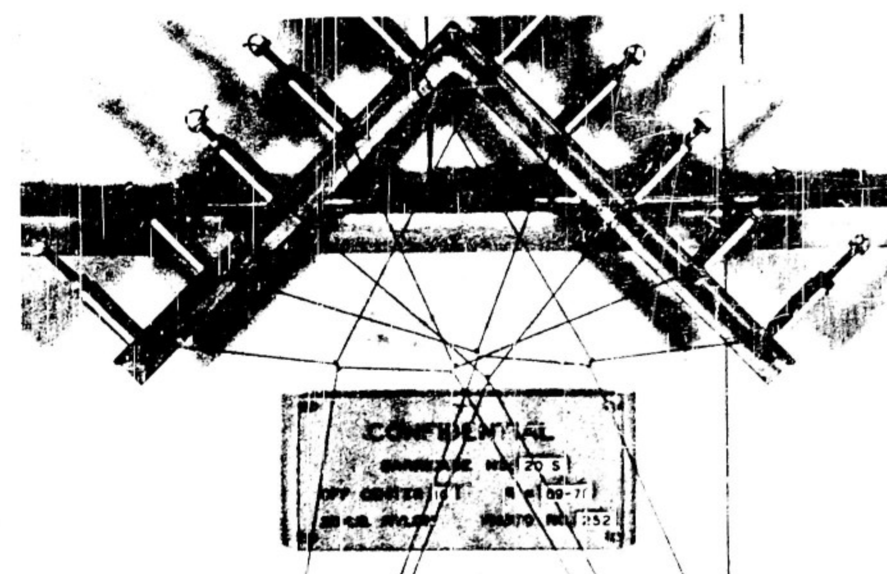

CONFIDENTIAL
20 S
18'
25-15
249


CONFIDENTIAL
BARRICADE NO. 20 S
OFF CENTER 6'
ft #147-33
20-LB. NYLON
PHOTO NO. 250


CONFIDENTIAL
20 S
231


CONFIDENTIAL
20 S
252

Barricade No. 20 S

Plane Wings Swept Back 45°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	25-15	47-33	73-57	89-71
Photo No.	245	246	247	248	249	250	251	252
F_1/T	.31	.40	.46	.47	.38	.43	.43	.50
F_2/T	.20	.30	.34	.35	.22	.28	.30	.31
F_3/T	.05	.06	.11	.12	.10	.04	.03	.06
F_4/T	.20	.30	.34	.35	.22	.22	.26	.30
F_5/T	.31	.40	.46	.47	.19	.24	.29	.36
F_6/T	.31	.40	.46	.47	.38	.43	.43	.50
F_7/T	.20	.30	.34	.35	.22	.28	.30	.31
F_8/T	.05	.06	.11	.12	.10	.04	.03	.06
F_9/T	.20	.30	.34	.35	.22	.22	.26	.30
F_{10}/T	.31	.40	.46	.47	.19	.24	.29	.36
Max. ϕ	41°	40°	39°	40°	29°	33°	36°	38°
Element	#1	#1	#1	#1	#1	#1	#1	#1

	On Center	16 ft. Off Center
Maximum F/T at any runout	0.47	0.50
Maximum angle ϕ at any runout	41°	38°
F_3/T at 40-foot runout	0	0.17
F_3/T at 80-foot runout	0	0.12
Torque/T at 40-foot runout	0	-1.1 ft.
Torque/T at 80-foot runout	0	-1.0 ft.

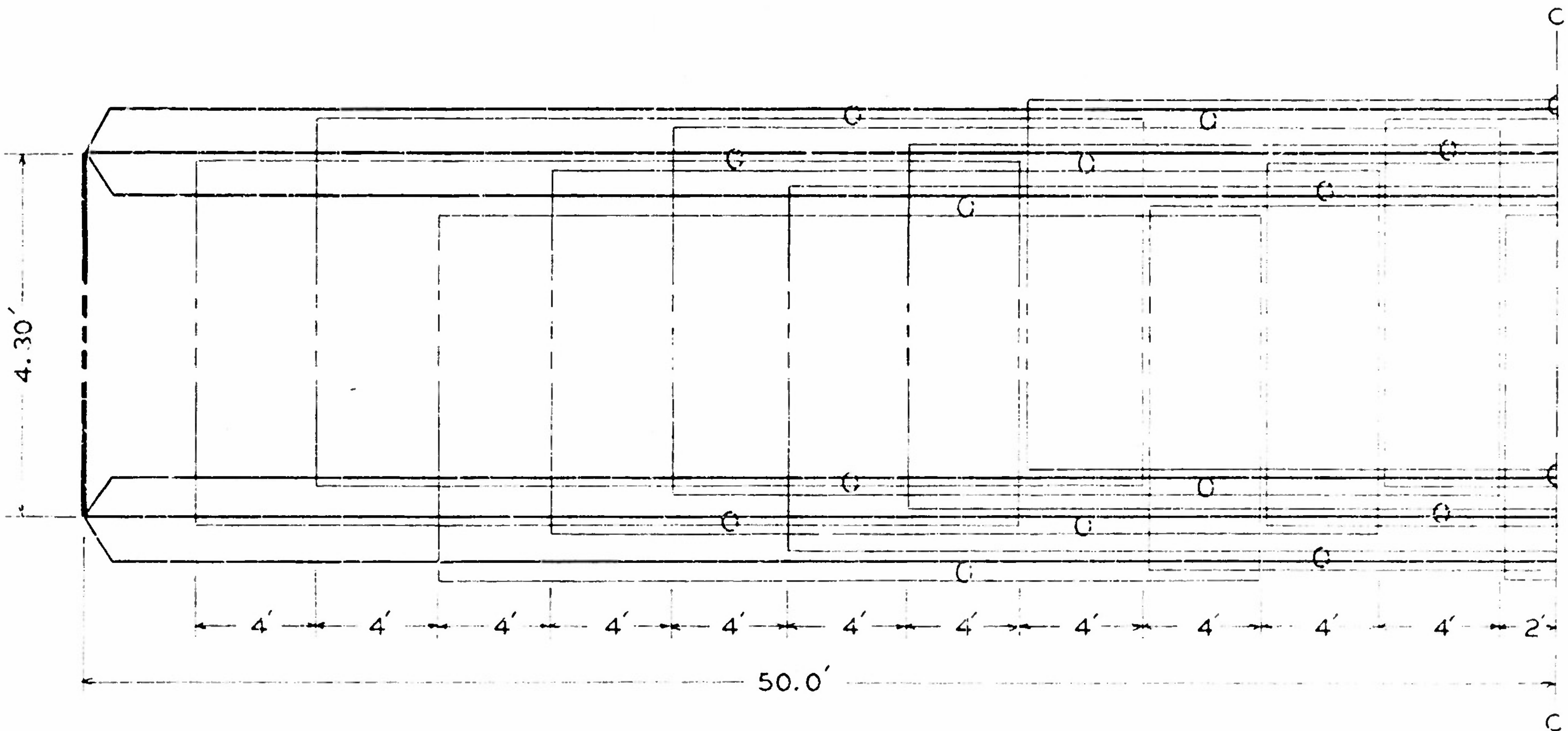
Barricade No. 21

Although Barricade Nos. 15 and 20 have some distinct advantages for planes with wings swept back 45°, they would be unsatisfactory for planes with wings swept back 60°. It is possible, however, to design a barricade similar in principle to No. 15 or to No. 20 which gives a comparable behavior for the larger angle of sweepback. Nos. 21 and 22 are barricades designed to engage planes with wings swept back 60°.

Barricade No. 21 is illustrated by the diagram on page 121. It is constructed of successive rectangular loops 28 feet long and 4.30 feet high, each loop being offset 4 feet horizontally from the preceding loop. The dimensions of each rectangular loop are such that when the loop is folded over the wing the elements of the loop can pull in directions perpendicular to the leading edges of the two wings. Each loop is connected to a pair of longitudinal elements by a ring at its top and a ring at its bottom. Both the loop and the longitudinal element are free to slide through the rings. Each third loop is connected to a common pair of longitudinal elements. Thus, three pairs of longitudinal elements are operative during an engagement, one rectangular loop being attached to each pair.

The series of photographs on pages 122 and 123 show respectively the behavior of this barricade when engaging in a center landing and a 16-foot off-center landing a plane with wings swept back 60°. Corresponding data are shown on page 124. Vertical elements at positions 4, 5, 6 and 7 are not shown engaged with the wings in the photographs, nor are data given for them in the table. Although these elements would actually be engaged, they would be inoperative; the rectangular loops of which they are parts each has but one of its two vertical elements engaged with the plane.

The forces in the vertical elements of this barricade are well distributed; however, they are significantly higher than those of the equivalent barricade (No. 15) for engaging a plane with wings swept back 45°. Here, as for No. 15 for the 45° sweepback, there is great chance of entanglement of elements with the tail fin as the longitudinal elements move across the fin during the runout. Barricade No. 22, to be discussed next, minimizes the tendency for the longitudinal elements to move across the tail fin, but does not eliminate chance for other entanglement. As was the case for No. 15 when engaging wings with a 45° sweepback, the force distribution in Barricade No. 20 when engaging a plane with wings swept back 60° is much less favorable for a landing in which the fuselage is not parallel to the center line of the deck than for a landing in which the fuselage is parallel to the center line.

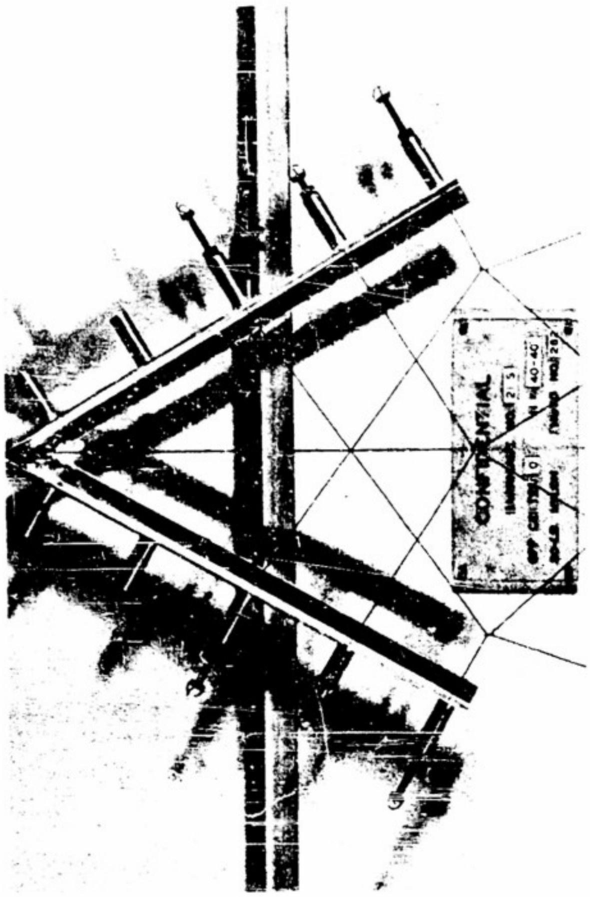


EACH LOOP IS
28 FT. LONG BY
4.30 FT. HIGH

BARRICADE NO. 21 DESIGN

SCALE 3/16" = 1'

CONFIDENTIAL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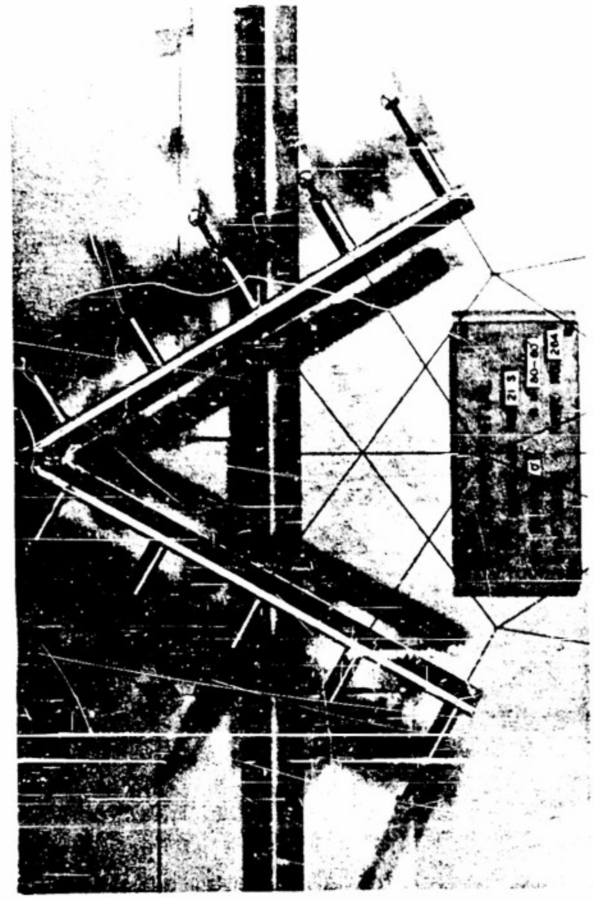
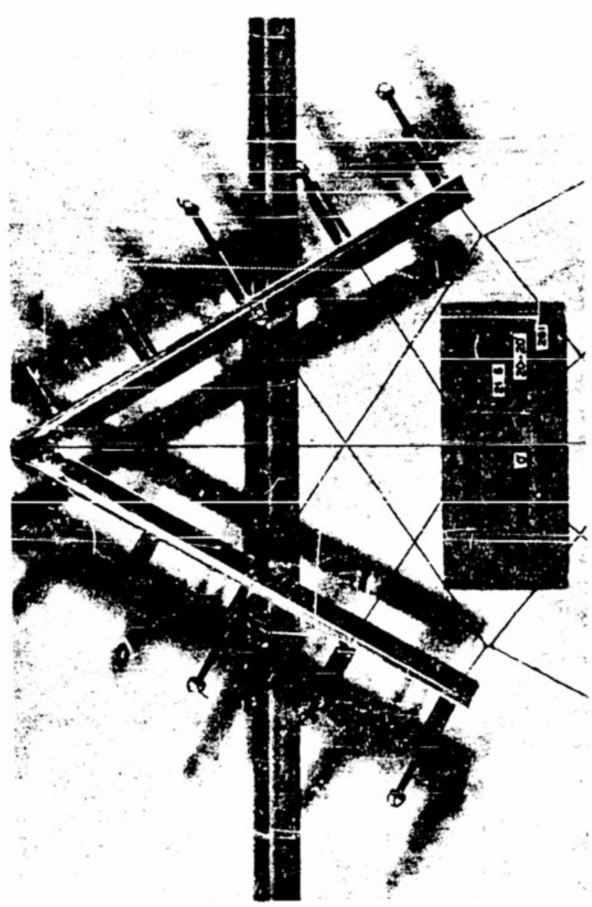
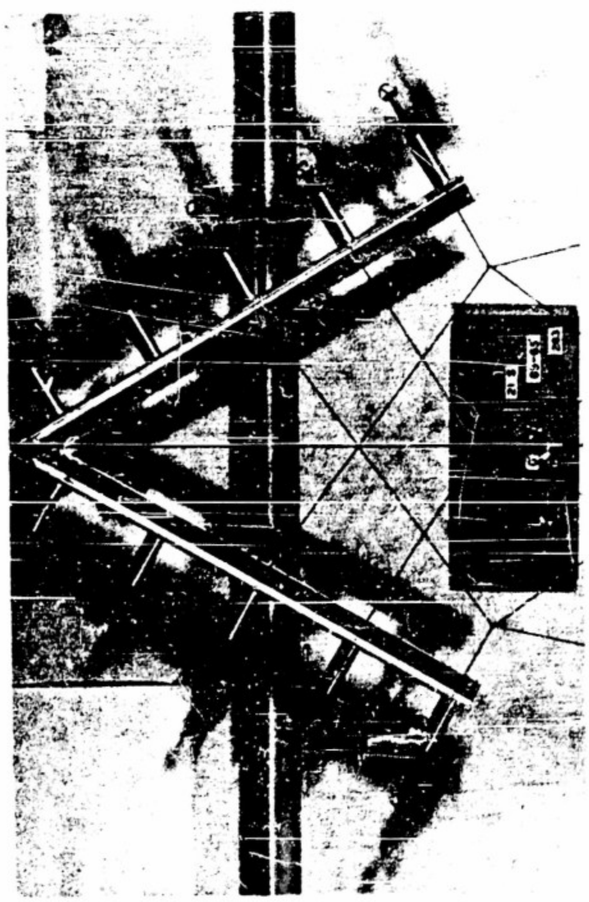
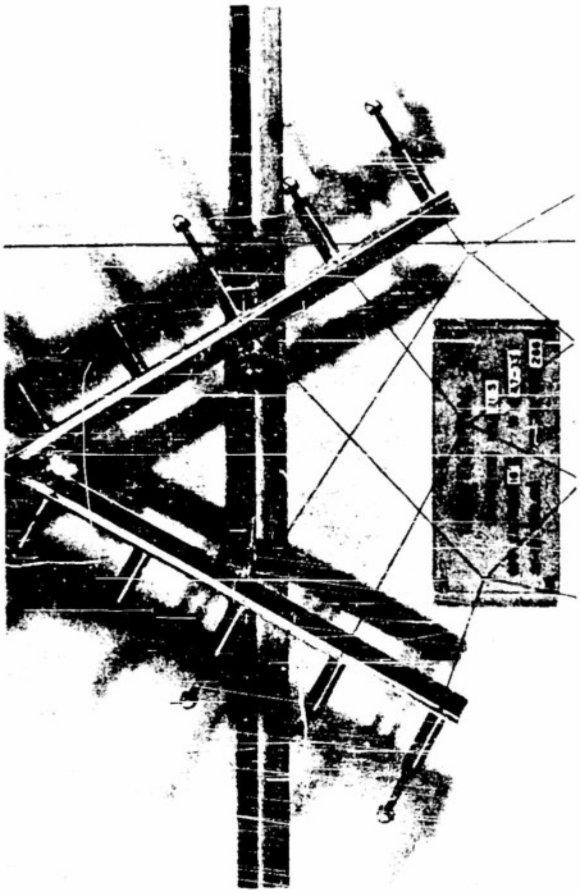
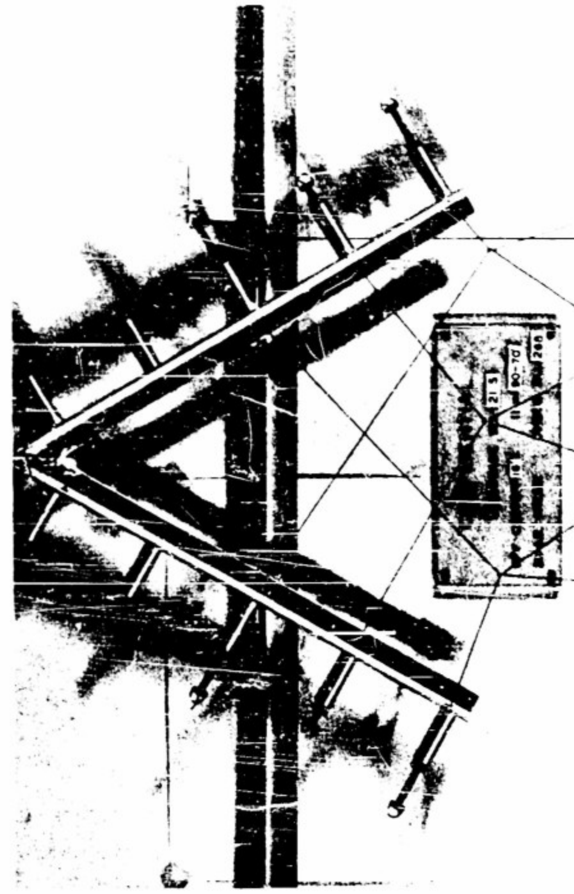
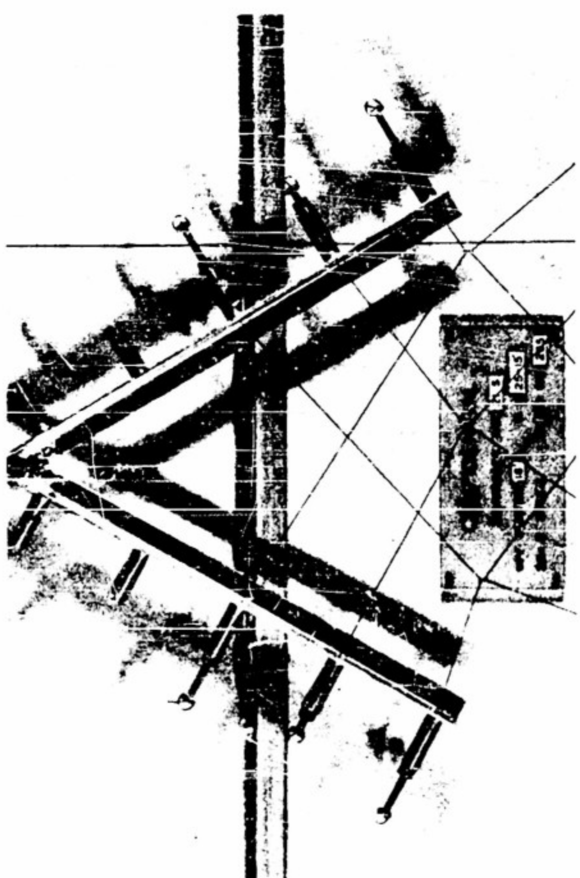


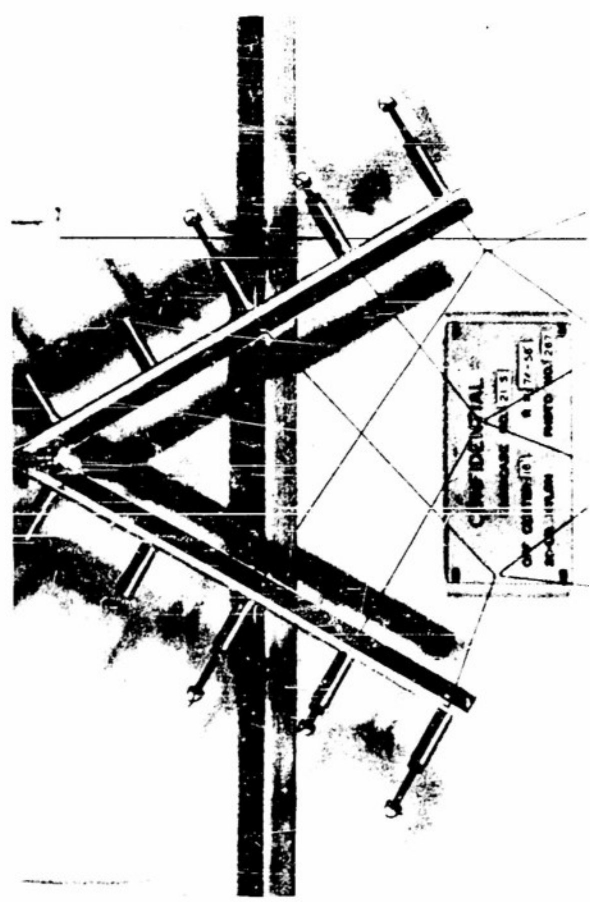












Barricade No. 21 S

Plane Wings Swept Back 60°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	25-15	47-33	74-56	90-70
Photo No.	261	262	263	264	265	266	267	268
F_1/T	.48	.54	.60	.61	.81	.81	.86	.94
F_2/T	.31	.35	.39	.42	.37	.39	.43	.50
F_3/T	.48	.54	.60	.61	.27	.35	.43	.52
F_4/T								
F_5/T								
F_6/T								
F_7/T								
F_8/T	.48	.54	.60	.61	.81	.81	.86	.94
F_9/T	.31	.35	.39	.42	.37	.39	.43	.50
F_{10}/T	.48	.54	.60	.61	.27	.35	.43	.52
Max. ϕ	7°	7°	7°	8°	13°	13°	13°	13°
Element	#1	#3	#3	#3	#8	#8	#8	#8

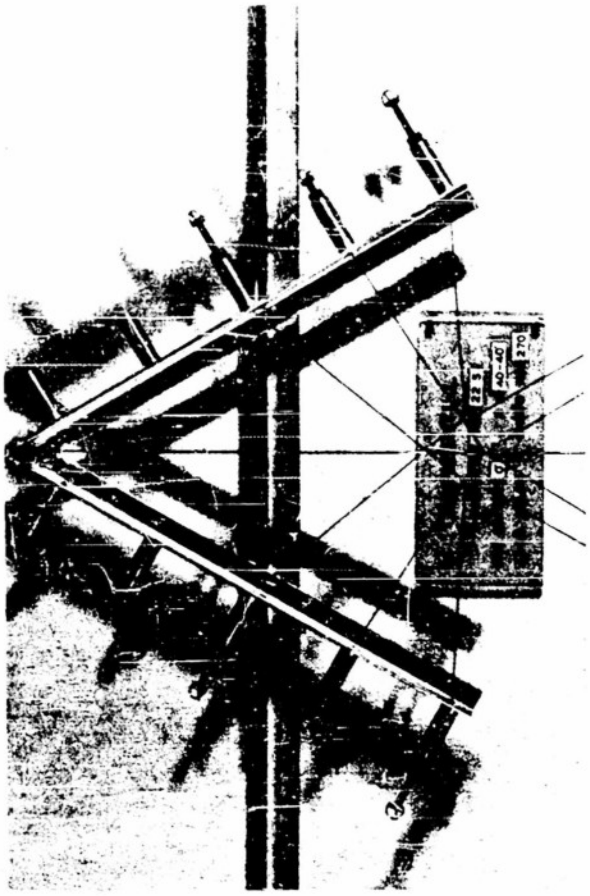
	On Center	16 ft. Off Center
Maximum F/T at any runout	0.61	0.94
Maximum angle ϕ at any runout	8°	13°
F_o/T at 40-foot runout	0	0.22
F_o/T at 80-foot runout	0	0.27
Torque/T at 40-foot runout	0	-3.2 ft.
Torque/T at 80-foot runout	0	-1.9 ft.

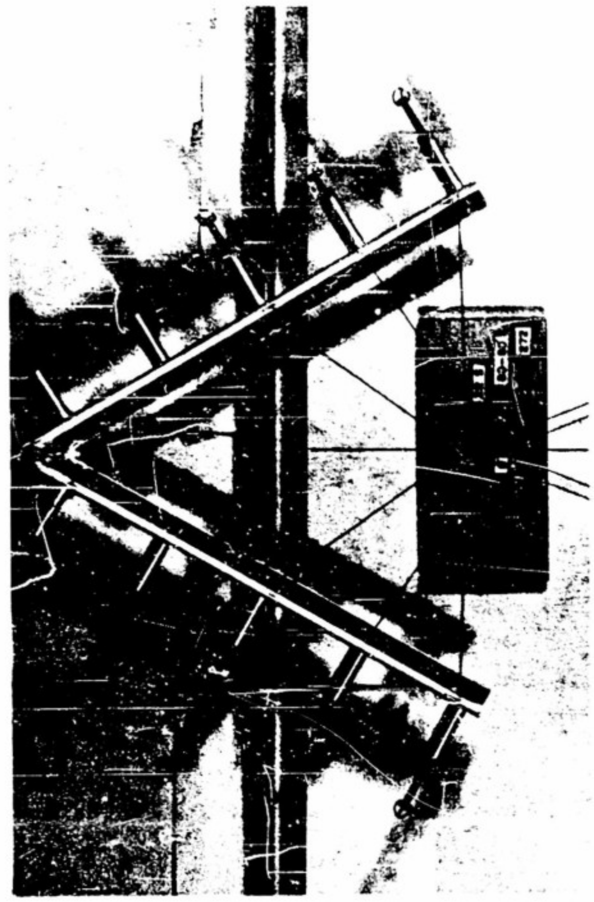
Barricade No. 22

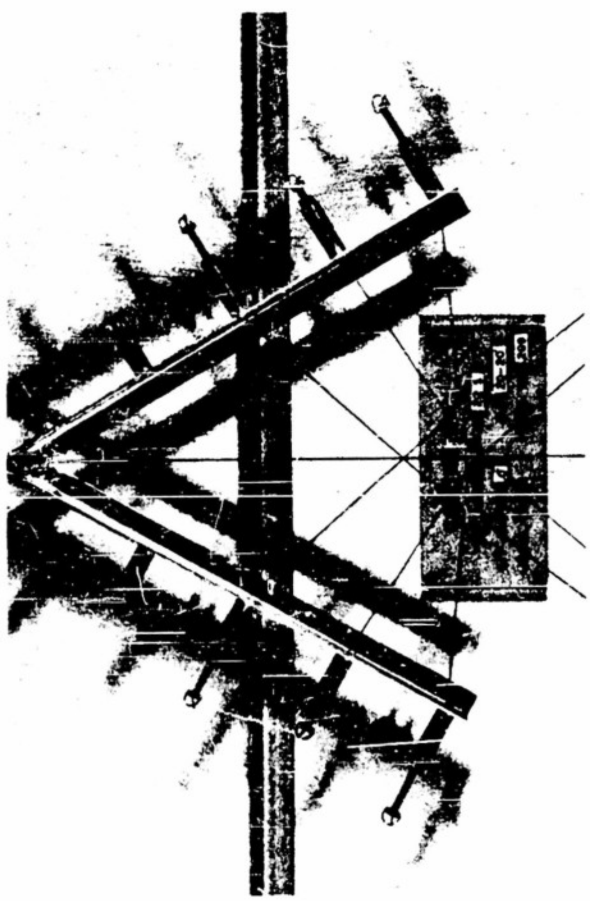
Barricade No. 22 is of the same design as No. 21 except for one feature. Whereas in No. 21 each third loop was connected by rings to a common pair of longitudinal elements, in No. 22 each second loop is connected to a common pair. (See photographs on page 126.) Thus, upon engaging a plane with wings swept back 60°, only two pairs of longitudinal elements of No. 22 are operative; there were three pairs operative during an engagement with No. 21. The design of No. 22 eliminates to a large extent movement of the longitudinal elements across the tail fin as the plane proceeds beyond the initial engagement. It also leads to a more favorable force distribution than No. 21 for a landing in which the fuselage is not parallel to the center line of the deck.

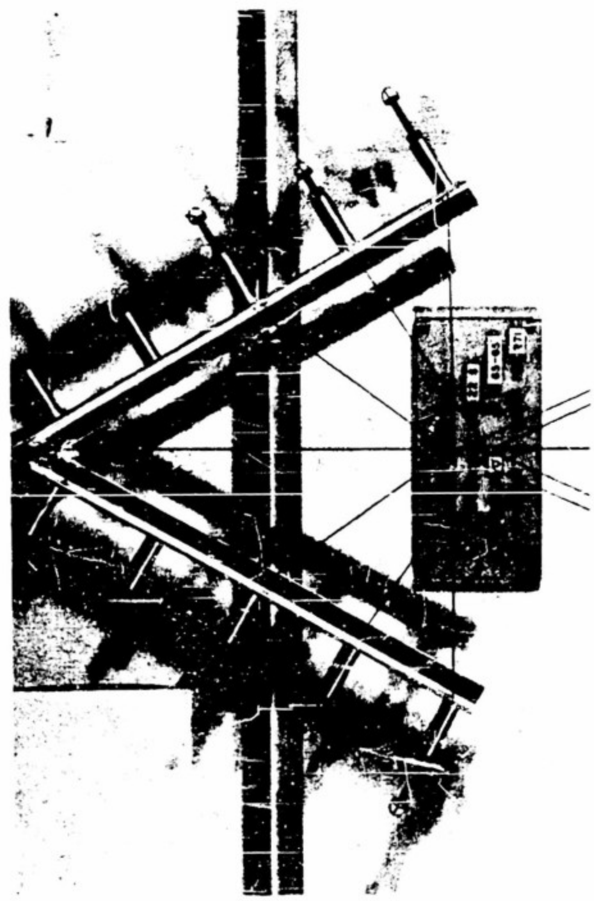
The series of photographs on pages 126 and 127 illustrate respectively the behavior of Barricade No. 22 when engaging in a center landing and a 16-foot off-center landing a plane with wings swept back 60°. The corresponding tabular data are shown on page 128. Vertical elements at positions 4, 5, 6 and 7 are not shown in the photographs; they are never operative as explained in discussing Barricade No. 21.

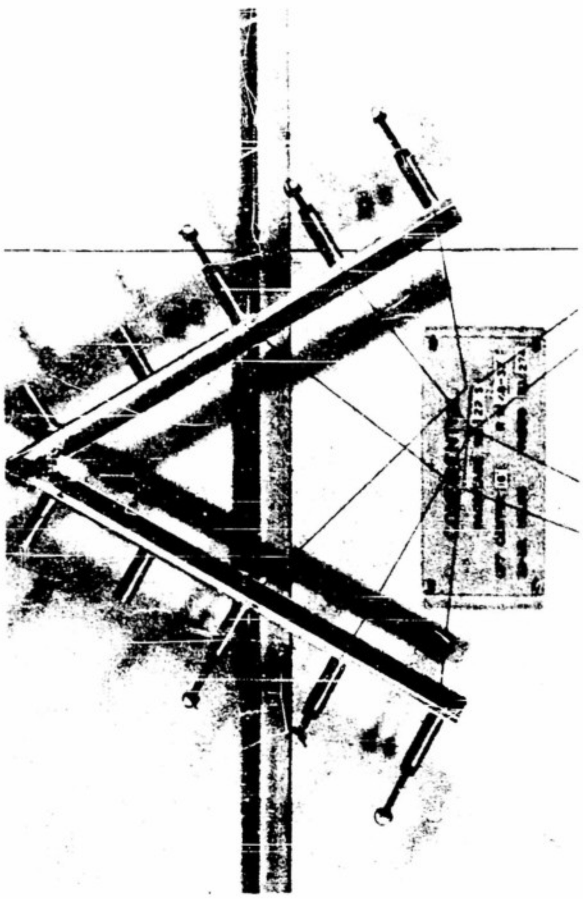
The distribution of forces in Barricade No. 22, particularly for a 16-foot off-center landing, is as satisfactory as the distribution was for Barricade No. 21. Furthermore, the maximum values of F/T and Ø for a 16-foot off-center engagement of No. 22 are not significantly different from the corresponding values for a center landing. The tendency for longitudinal elements to move across the tail fin is much less for No. 22 than for No. 21. Unfortunately in No. 22 as well as in No. 21 the loops engaging the plane wings extend back sufficiently far that the tail fin would interfere with the loops themselves. Inspection of either the design or the photographs shows that Barricade No. 22 is superior to No. 21 in another respect. For No. 22 the force distribution is much the same for a landing in which the fuselage is not parallel to the center line of the deck as it is for a landing in which the fuselage is parallel to the center line.

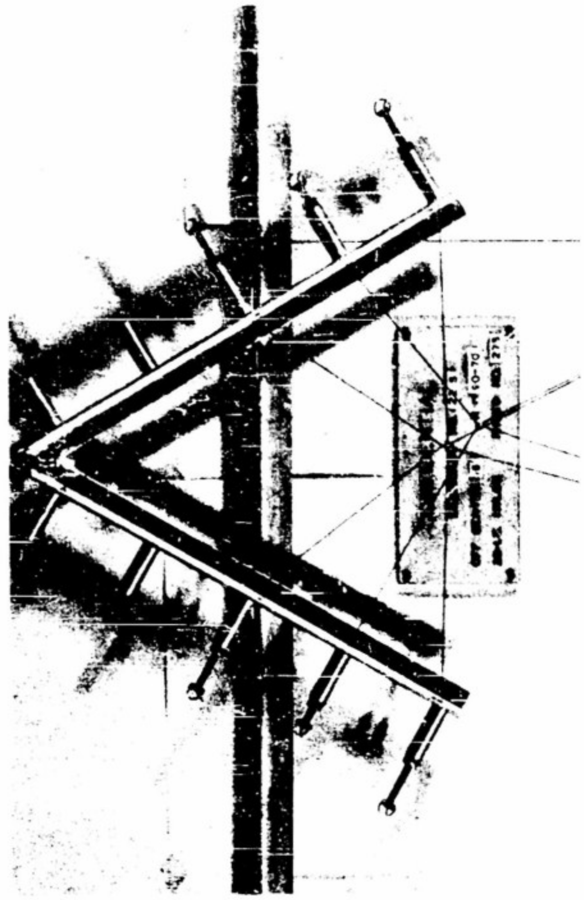


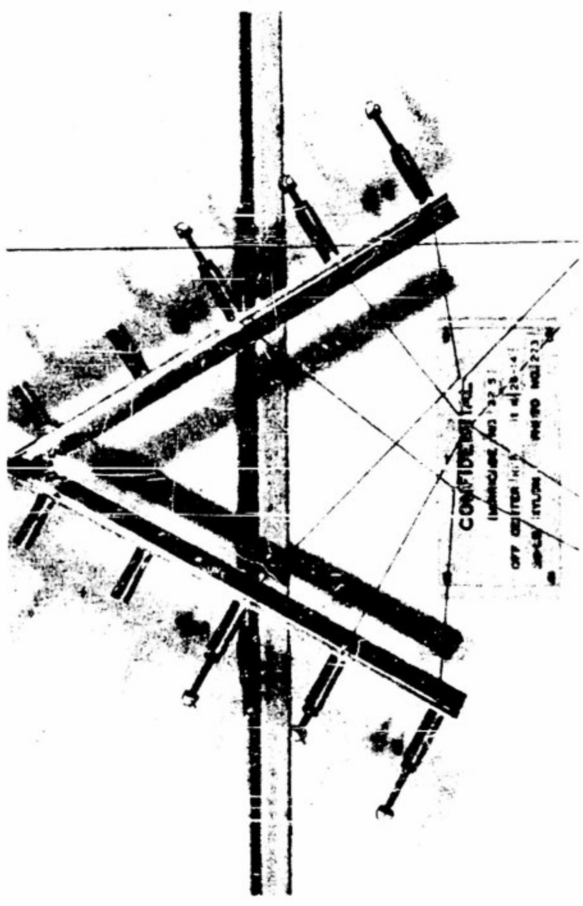


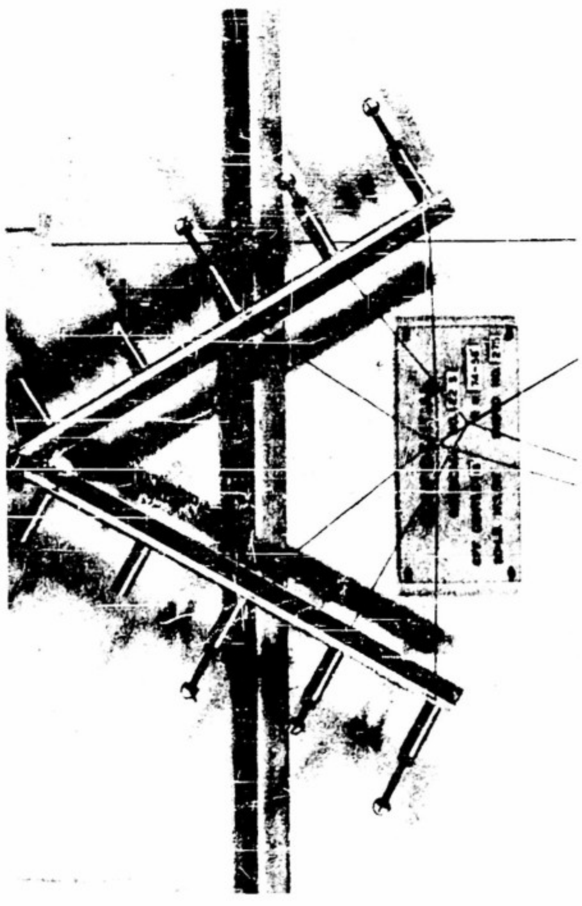












Barricade No. 22 S

Plane Wings Swept Back 60°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	26-14	48-32	74-56	90-70
Photo No.	269	270	271	272	273	274	275	276
F_1/T	.62	.69	.71	.77	.66	.82	.74	.72
F_2/T	.37	.37	.42	.52	.32	.39	.44	.47
F_3/T	.62	.69	.71	.77	.41	.57	.57	.63
F_4/T								
F_5/T								
F_6/T								
F_7/T								
F_8/T	.62	.69	.71	.77	.66	.82	.74	.72
F_9/T	.37	.37	.42	.52	.32	.39	.44	.47
F_{10}/T	.62	.69	.71	.77	.41	.57	.57	.63
Max. ϕ	25°	26°	28°	29°	24°	24°	28°	28°
Element	#1	#1	#1	#1	#1	#1	#1	#1

	On Center	16 ft. Off Center
Maximum F/T at any runout	0.77	0.82
Maximum angle ϕ at any runout	29°	28°
F_c/T at 40-foot runout	0	0.18
F_c/T at 80-foot runout	0	0.12
Torque/T at 40-foot runout	0	1.2 ft.
Torque/T at 80-foot runout	0	0.5 ft.

Barricade No. 23

It is possible that a barricade built in two sections in such a manner that one or more elements of each section engage the plane in a scissors-like manner might be advantageous in stopping planes with sweptback wings. While in principle the scissors-like action might take place in either a vertical or a horizontal plane, it appears that the horizontal arrangement would have several advantages. Barricade No. 23 was designed to operate in this manner. Its construction is shown by the diagram on page 131. That part of the barricade connected to the port purchase cable is entirely separate, except perhaps for light sewing, from that part connected to the starboard purchase cable. As the nose of the plane engages the barricade and passes between adjacent vertical elements, that part of the barricade attached to the port purchase cable will pull on the starboard wing of the plane; that part of the barricade attached to the starboard purchase cable will pull on the port wing of the plane. Such a design will obviously lead to rather large forces in certain of the vertical elements, but it has a number of distinct advantages over other designs.

In making observations on this particular barricade only the two vertical elements nearest the nose of the plane, one on either side of the nose, were attached to the wings at the points where they originally come into contact with the leading edge. There would be little tendency for these two elements to slip. Other vertical elements, all of which would have a tendency to slip a limited distance, were attached to the wings at the approximate positions they would assume after slipping. The photographs show 10 elements engaged with the 45° swept-back wings, and 14 elements engaged with the 60° sweptback wings. In the latter case the elements engaging the plane are numbered consecutively from 1 to 14, starting at the port side.

The series of photographs on pages 132 and 133 illustrate respectively the behavior of this barricade as it engages a plane with wings swept back 45° in a center landing and a 16-foot off-center landing. The corresponding tabular data are shown on page 134. The series of photographs on pages 135 and 136 show the behavior of the barricade engaging a plane with wings swept back 60° in a center landing and a 16-foot off-center landing. Corresponding tabular data are shown on page 137.

Barricade No. 23 has several distinct advantages and one somewhat serious disadvantage. The following conclusions can be drawn from the tables and photographs.

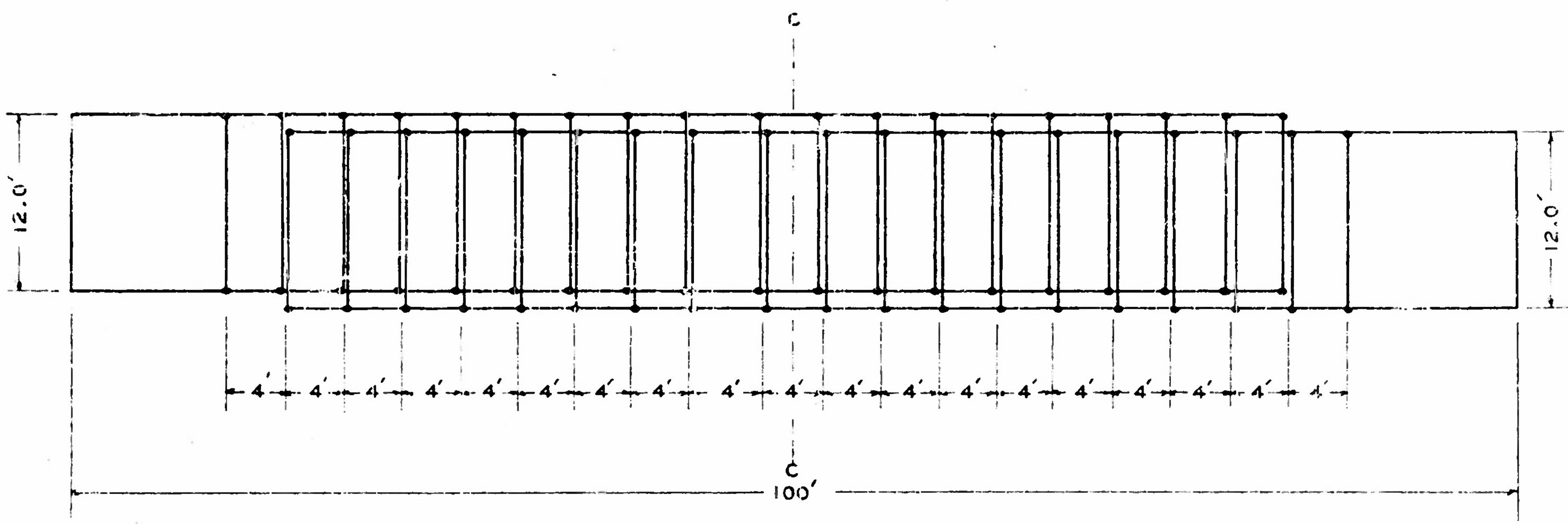
1. As regards the maximum angle ϕ, the component of force toward the center line of the deck, and the torque exerted on the plane, Barricade No. 23 is as satisfactory for engaging a plane with wings swept back either 45° or 60° as Barricade No. 10 is for engaging a plane with straight wings.

2. Barricade No. 23 offers little or no chance of entanglement with the tail fin during engagements with planes having sweptback wings.

3. Should a vertical element of Barricade No. 23 fail, the barricade does not become inoperative; another element which had been inoperative accepts the load under circumstances which are not much more unfavorable than those under which the first element operated.

4. Although Barricade No. 23 exerts its major forces on the plane at points considerably ahead of the center of mass of the plane, any tendency of the plane to skew immediately produces a torque which opposes the skew.

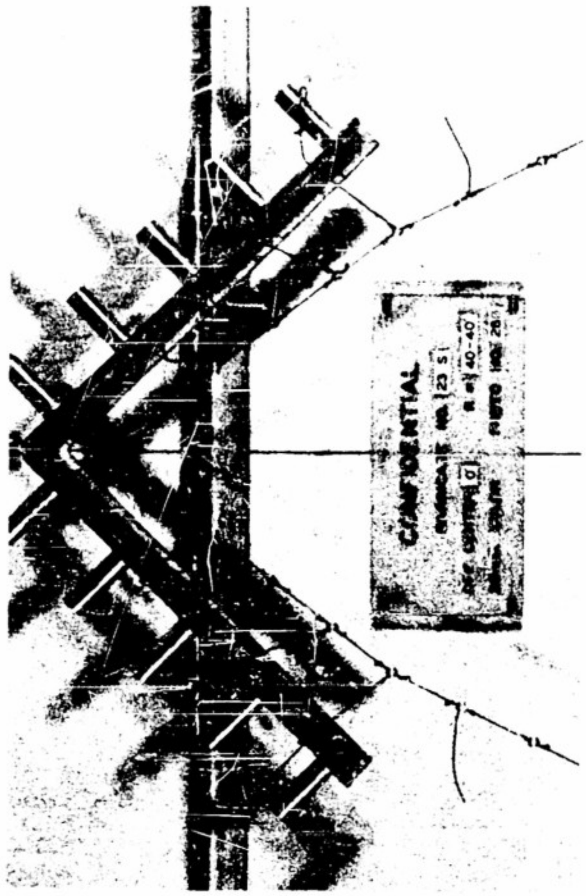
5. The major defect of Barricade No. 23 is the fact that the two vertical elements located immediately next to and on either side of the fuselage must provide nearly the entire force to stop the plane. The ratio F/T in these two elements is 1.00 or slightly under. It is not greatly different for a center and an off-center landing; nor is it greatly different for a plane with wings swept back 45° and one with wings swept back 60°; nor is it greatly different for a landing in which the fuselage is not parallel to the center line of the deck and one in which the fuselage is parallel to the center line. The forces in these two elements are approximately twice the maximum forces encountered in a 16-foot off-center engagement of Barricade No. 10 with a straight-wing plane. The fact that these forces are localized at points where the leading edges of the sweptback wings join the fuselage is both advantageous and disadvantageous. The localization will require that the wing withstand a large force; but the force is applied at the strongest part of the wing. Localization of these forces at points considerably ahead of the center of mass of the plane would provide a degree of instability; this tendency would probably be offset satisfactorily by the large restoring torque brought into play by any degree of skew.



BARRICADE NO. 23 DESIGN

SCALE $3/32'' = 1'$

CONFIDENTIAL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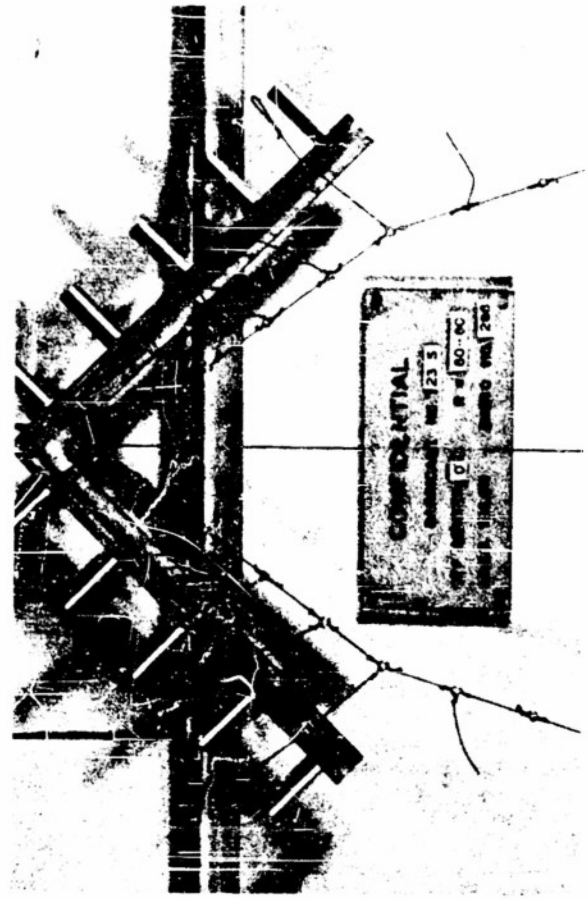
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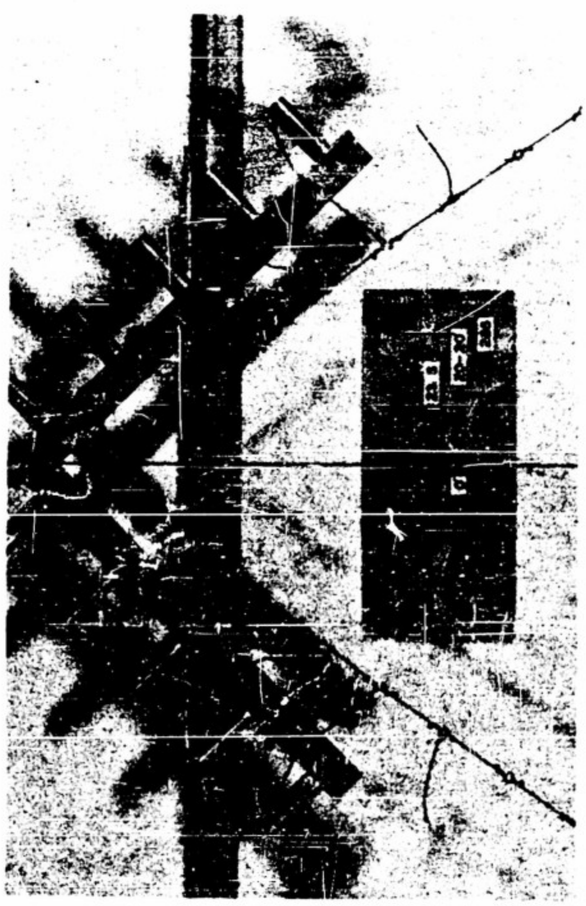
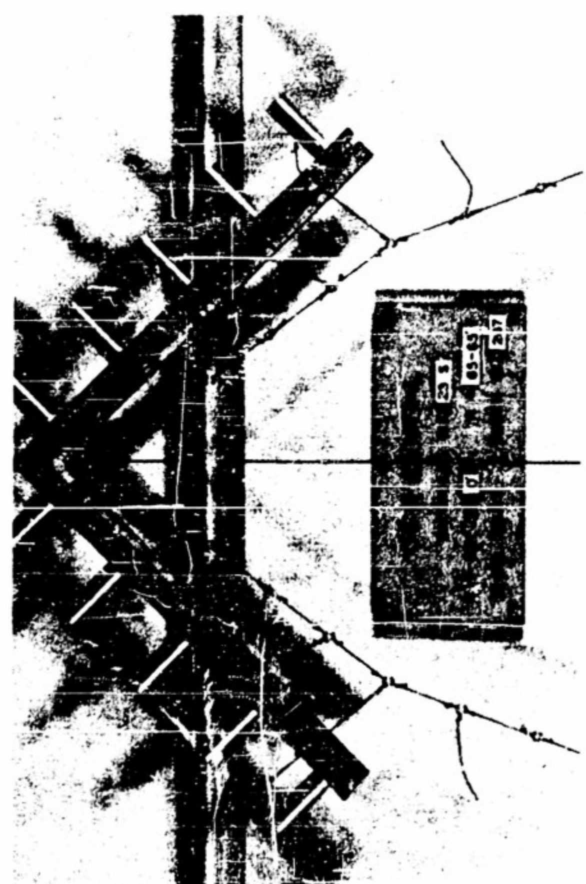
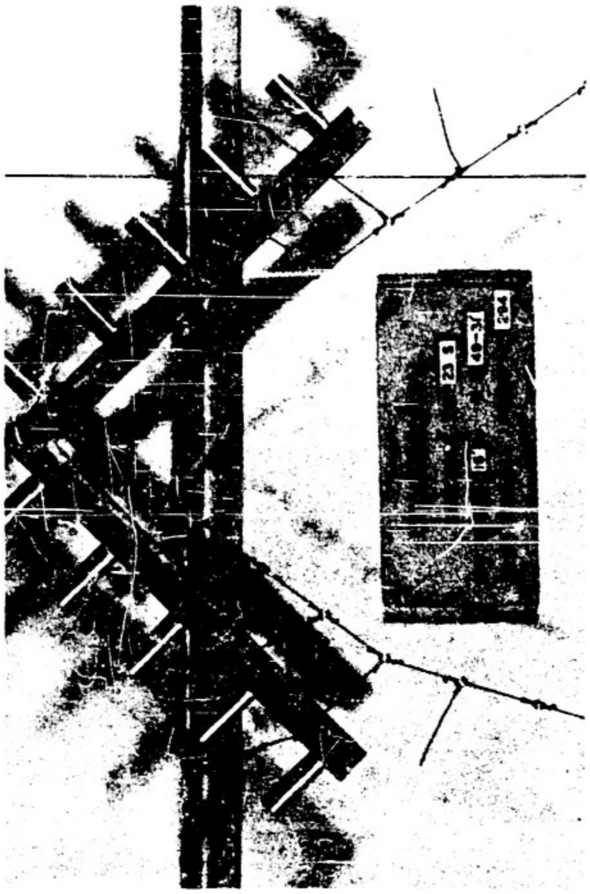
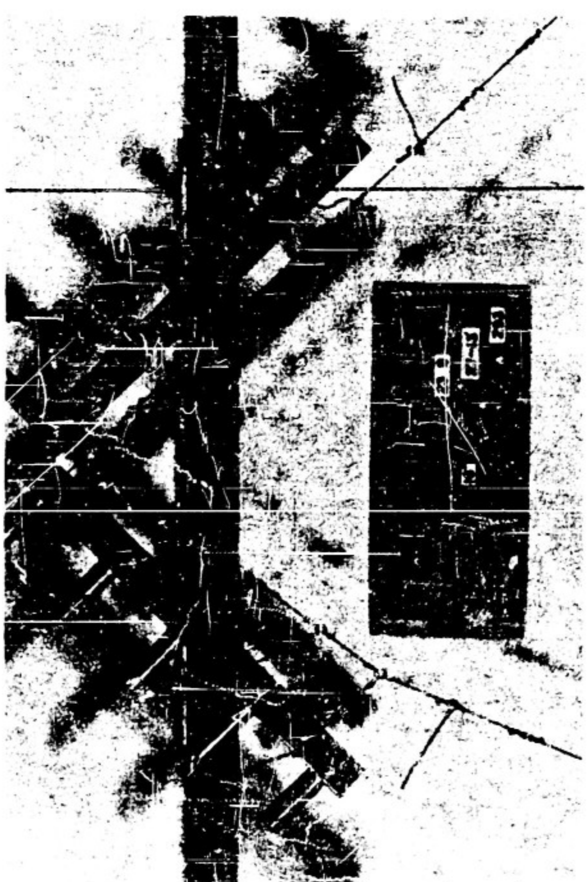
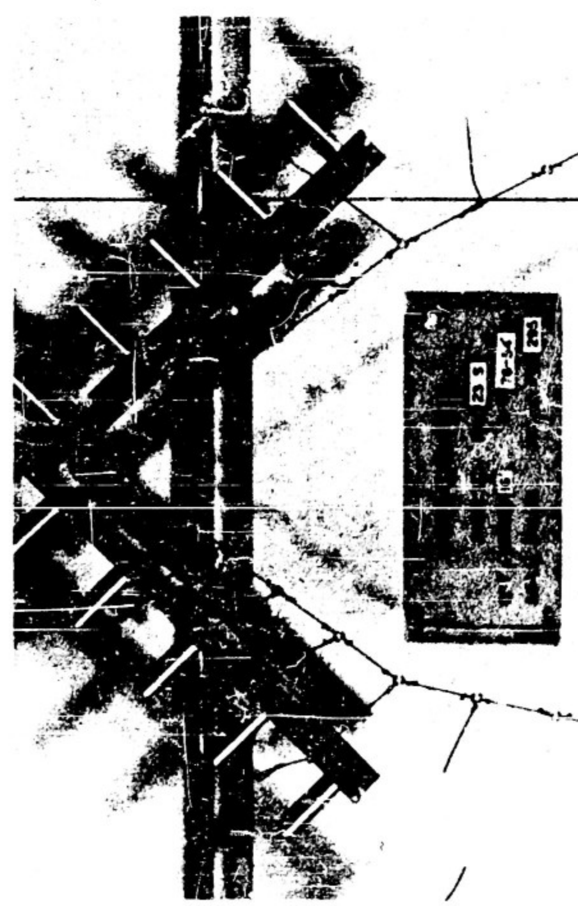










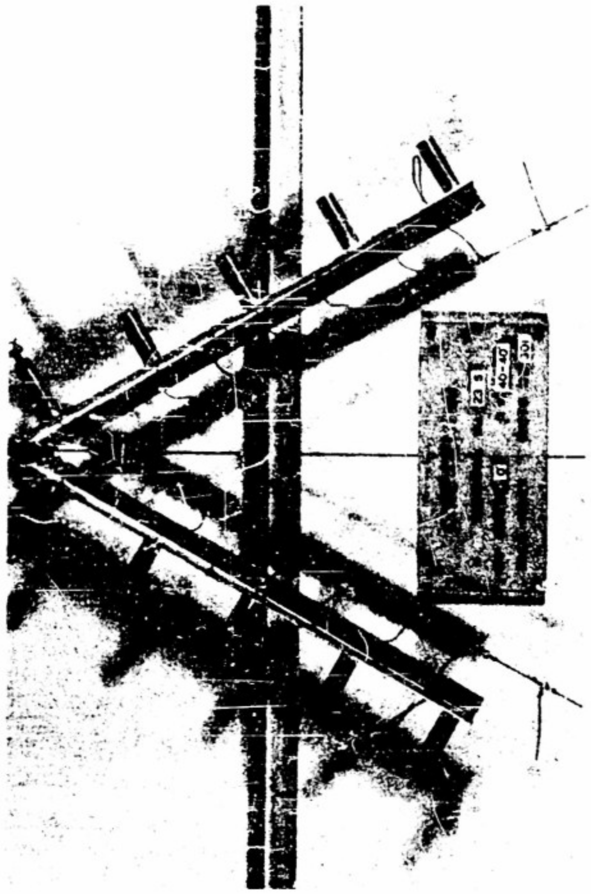
Barricade No. 23 S

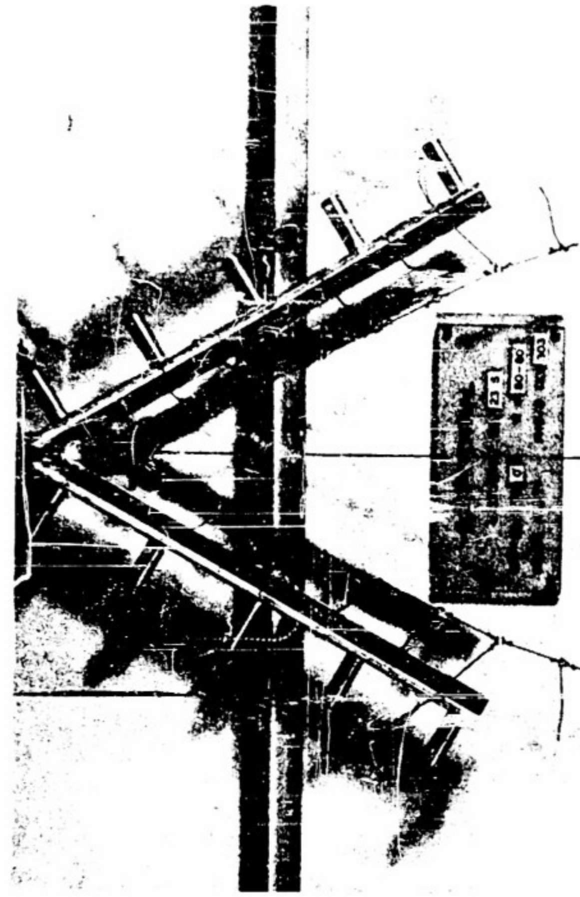
Plane Wings Swept Back 45°

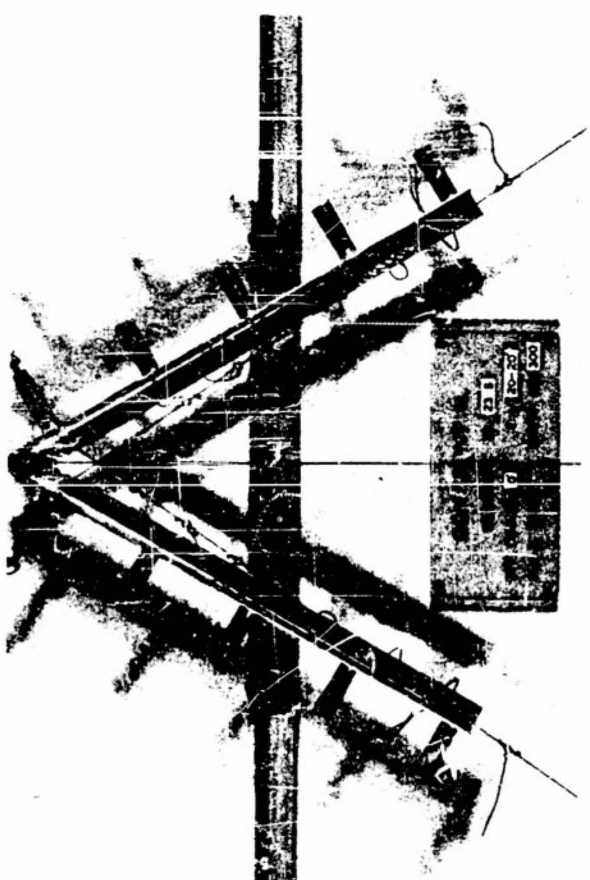
Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

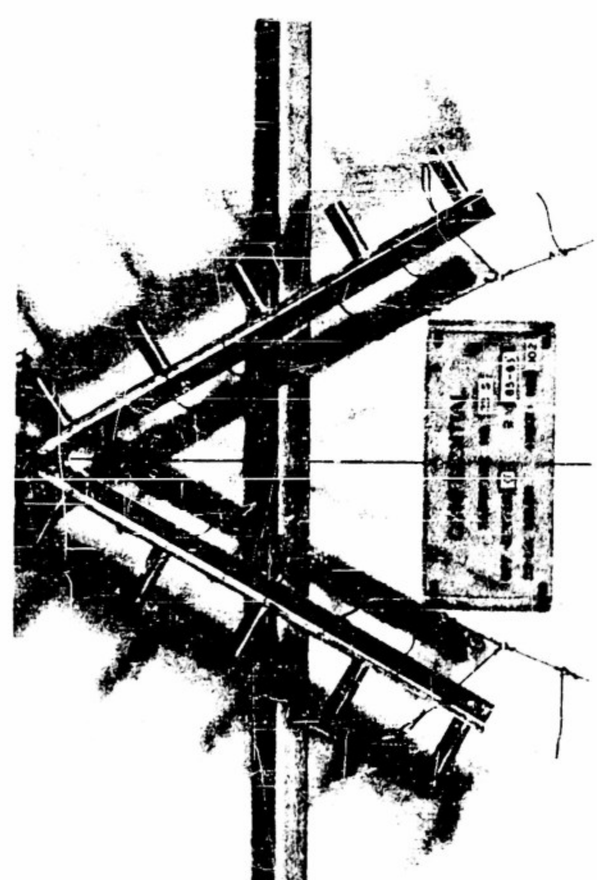
	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	27-13	49-31	76-54	91-69
Photo No.	285	286	287	288	293	294	295	296
F_1/T	.06	.20	.29	.33	.26	.35	.42	.45
F_2/T	0	0	0	0	0	0	0	0
F_3/T	0	0	0	0	0	0	0	0
F_4/T	0	0	0	0	0	0	0	0
F_5/T	.92	.89	.87	.80	.96	.98	.90	.84
F_6/T	.92	.89	.87	.80	.90	.85	.80	.75
F_7/T	0	0	0	0	0	0	0	0
F_8/T	0	0	0	0	0	0	0	0
F_9/T	0	0	0	0	0	0	0	0
F_{10}/T	.05	.18	.28	.32	0	.04	.15	.21
Max. ϕ	8°	9°	9°	9°	9°	9°	9°	9°
Element	#6	#6	#6	#6	#6	#6	#6	#6

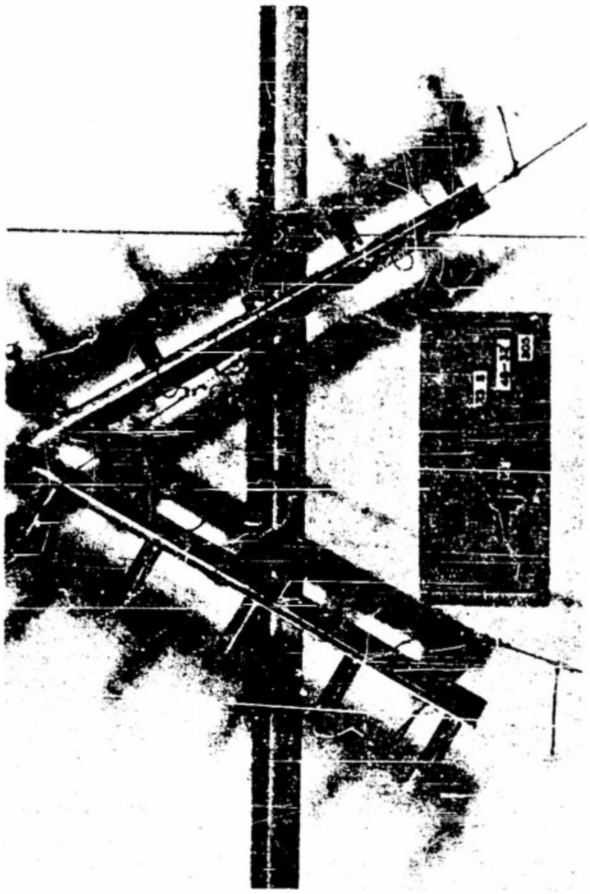
	On Center	16 ft. Off Center
Maximum F/T at any runout	0.92	0.98
Maximum angle ϕ at any runout	9°	9°
F_o/T at 40-foot runout	0	0.30
F_o/T at 80-foot runout	0	0.13
Torque/T at 40-foot runout	0	-3.8 ft.
Torque/T at 80-foot runout	0	-3.9 ft.

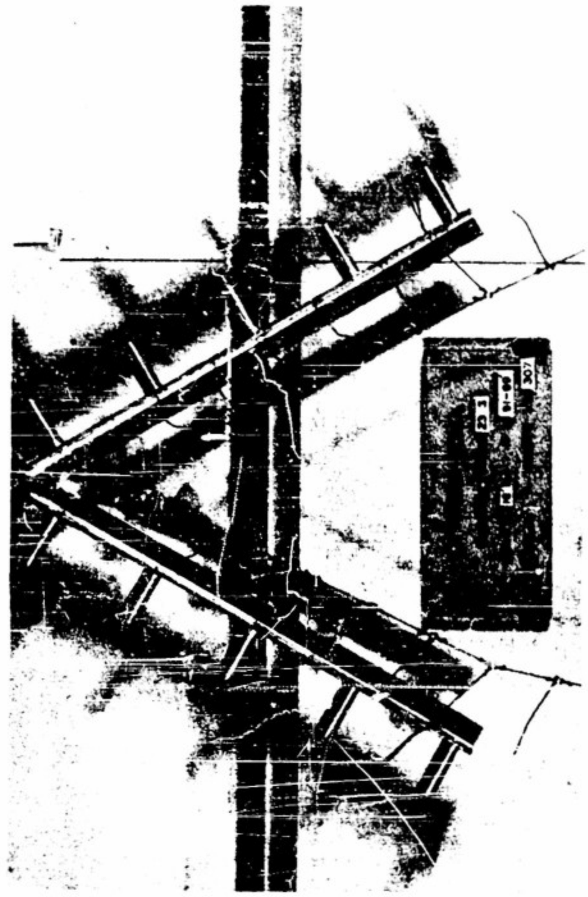


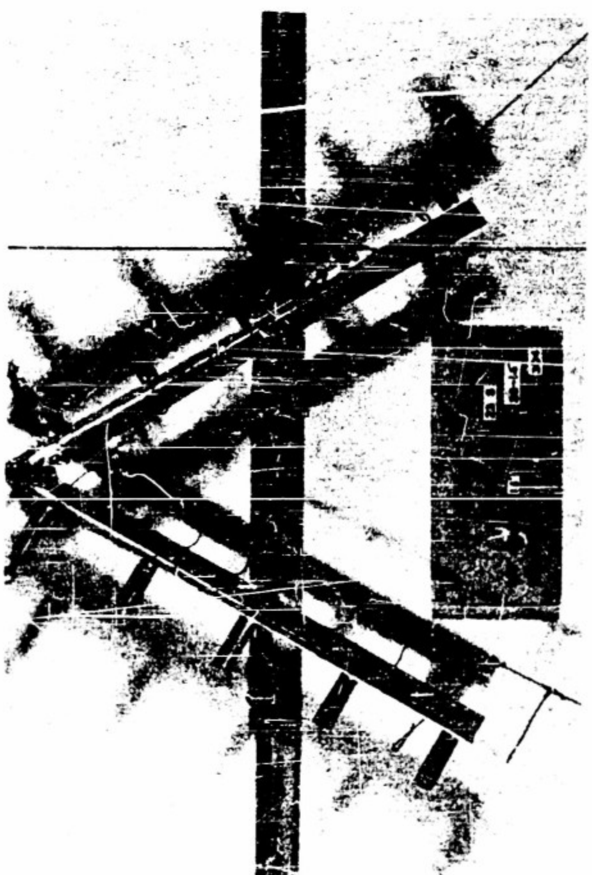


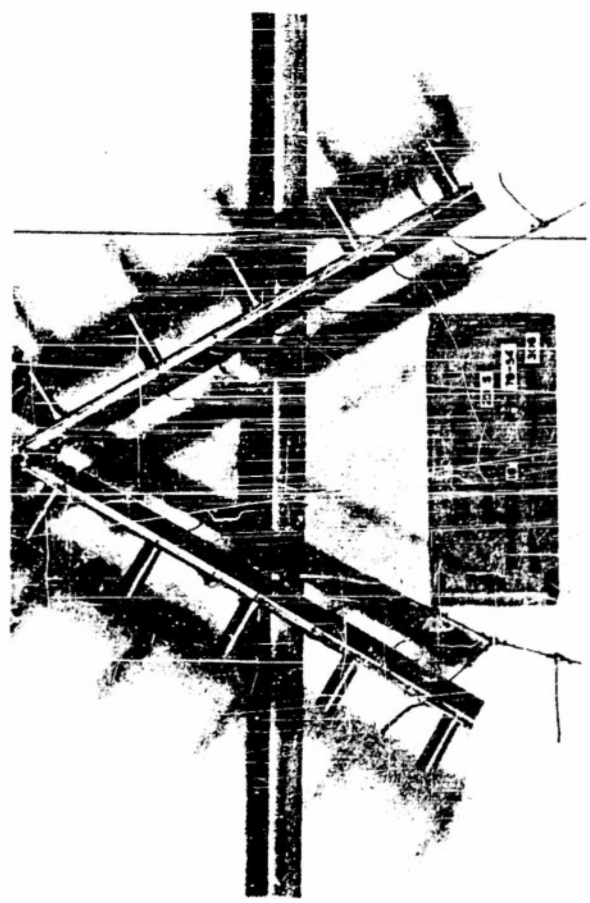












Barricade No. 23 S

Plane Wings Swept Back 60°

Singly Reeved
Amount Off Center Indicated Below
Barricade of 20-lb. Nylon
T = 2000 grams

	On Center				16 ft. Off Center			
R	20-20	40-40	65-65	80-80	26-14	48-32	76-54	91-69
Photo No.	300	301	302	303	304	305	306	307
F_1/T	0	0	.09	.13	0	.14	.24	.26
F_2/T	0	0	0	0	0	0	0	0
F_3/T	0	0	0	0	0	0	0	0
F_4/T	0	0	0	0	0	0	0	0
F_5/T	0	0	0	0	0	0	0	0
F_6/T	0	0	0	0	0	0	0	0
F_7/T	1.00	1.00	.98	.95	1.00	1.00	1.00	1.00
F_8/T	1.00	1.00	.98	.95	1.00	.94	.90	.87
F_9/T	0	0	0	0	0	0	0	0
F_{10}/T	0	0	0	0	0	0	0	0
F_{11}/T	0	0	0	0	0	0	0	0
F_{12}/T	0	0	0	0	0	0	0	0
F_{13}/T	0	0	0	0	0	0	0	0
F_{14}/T	0	0	.09	.13	0	0	0	.01
Max. ϕ	26°	33°	34°	34°	34°	34°	34°	34°
Element	#7	#7	#7	#7	#8	#8	#8	#8

	On Center	16 ft. Off Center
Maximum F/T at any runout	1.00	1.00
Maximum angle ϕ at any runout	34°	34°
F_c/T at 40-foot runout	0	0.26
F_c/T at 80-foot runout	0	0.25
Torque/T at 40-foot runout	0	0.3 ft.
Torque/T at 80-foot runout	0	-3.4 ft.

SUMMARY OF BARRICADE CHARACTERISTICS (SWEPTBACK WINGS)

Collected in the following table are the measured characteristics of all barricades for which engagements with sweptback wings were studied. All data are for static conditions. No allowance has been made for the variable thickness of the wing.

Comparison of Barricades (Sweptback Wings)

Bar. No.	Sweep-Back	Off Center	Max. F/T	Max. ϕ	F_a/T		Torque/T	
					R=40'	R=80'	R=40'	R=80'
10 S	45°	0 16	.55 .52	44° 49°	0 .28	0 .31	0 -3.6	0 -4.1
	60°	0 16	.90 .92	62° 67°	0 .23	0 .24	0 1.2	0 -1.1
13 S	45°	0 16	.76 .82	29° 29°	0 .38	0 .46	0 -6.2	0 -9.6
	60°	0 16	.92 1.10	45° 47°	0 .28	0 .23	0 .27	0 -3.2
15 S	45°	0 16	.38 .54	16° 22°	0 .25	0 .26	0 -6.1	0 -3.8
20 S	45°	0 16	.47 .50	41° 38°	0 .17	0 .12	0 -1.1	0 -1.0
21 S	60°	0 16	.61 .94	8° 13°	0 .22	0 .27	0 -3.2	0 -1.9
22 S	60°	0 16	.77 .82	29° 28°	0 .18	0 .12	0 1.2	0 .5
23 S	45°	0 16	.92 .98	9° 9°	0 .30	0 .13	0 -3.8	0 -3.9
	60°	0 16	1.00 1.00	34° 34°	0 .26	0 .25	0 .3	0 -3.4

CONCLUSIONS

The measured static characteristics of a number of possible barricades for engaging planes with straight wings have been summarized in the table on page 88. Similar measured characteristics of possible barricades for engaging planes with sweptback wings have been summarized on page 138. Certain conclusions concerning many of the barricades studied have been discussed in the sections in which the respective data were presented. Conclusions presented here will therefore be of a somewhat more general nature.

The group is fully aware of the limitations of the data presented in this report. They are all for static conditions, whereas dynamic conditions actually prevail. The difference between dynamic and static characteristics will often be quite significant. No allowance has been made for the fact that barricade elements will slip along the leading edges of the wings, though it is recognized that slippage may influence the situation considerably. No allowance has been made for the fact that the wings of conventional planes are swept back at a small angle, nor for the fact that wings are thicker near the fuselage than near the tip. All observations were made using 20-lb. nylon as a barricade material, and the barricade elements were subjected to tensions far below their breaking strength. Elements engaged with the wings of a model plane suffered elongations of from 2 to 7 per cent, whereas the percentile elongations in an actual barricade would be much greater.

In spite of limitations of the data, consideration of the general barricade problem, aided materially by the studies presented in this report, has led the group to the following conclusions:

1. Neglecting all other operations which prescribe and limit space assignment on the landing deck, it seems clear that the best solution to the barricade problem would be to dispense with the barricade and let those few planes which are not stopped by an arresting cable or a barrier go into the sea. The average injury to personnel and damage to planes which would result from this procedure would probably be less than it is from attempting to stop these planes with the conventional barricade. Future increases in the speeds of planes, coupled with the certain use of sweptback wings, will increase materially the difficulty of providing a satisfactory barricade of the conventional type. Even apart from the possibility of using a "going-into-the-sea barricade," there is much to be said for the existence of separate and simultaneously usable launching, landing and parking facilities. The desirability of such facilities is greater on a large carrier having a correspondingly larger complement of planes, than on a small carrier. It is the opinion of this group that

the advantages of separate facilities will ultimately lead to their installation on large carriers, and that in such instance the conventional barricade should be eliminated and the plane allowed to go into the sea.

2. The small or medium carrier, which certainly warrants a place in the over-all carrier picture, presents a different problem. Separate launching, landing and parking facilities can probably never be provided without an untenable reduction in the plane complement. Some deck barricade will probably always be necessary. There appear to be only two ways in which its use might be avoided. One way would be to land all incoming planes on the surface of the sea rather than on the deck of the carrier. Although it is too early to evaluate the results of studies of surface landings now being made, this group is not at all optimistic that surface landings on the sea will ever prove sufficiently satisfactory that they can be utilized exclusively in carrier operation. If they cannot be used exclusively their utilization would not allow elimination of the barricade. Another way of avoiding use of a barricade would be to reduce materially the safe landing speeds of planes. A sufficient reduction can probably be accomplished only through use of some lift such as that provided in the helicopter. Addition of facilities to provide such a lift would certainly reduce the plane performance materially. It appears very doubtful to this group that the Navy will wish to sacrifice the maximum performance that can be attained. It therefore seems likely that some form of barricade will always be necessary on small and medium carriers.

3. From general consideration of the requirements which should be met by a barricade, one can scarcely escape the conclusion that the barricade should behave in many respects like a flexible rubber diaphragm the rubber of which is capable of great stretch before failure. Lack of a material which can be stretched sufficiently without failure and at the same time meet other requirements of strength, durability, etc., will probably make it necessary to employ a finite number of elements instead of a continuum. Outside of necessary strength and durability, the most important property of the barricade material is its ability to suffer great stretch without failure. Without considerable stretch there is little hope of equalizing even approximately the stresses in various parts of the barricade.

4. In comparing different possible barricade designs, it is surprising how little difference there really is between the force distribution in the best design and that in the poorest design. Likewise, for an off-center landing, it is surprising how little the design affects the magnitude or direction of the component of force exerted on the plane toward the center line of the deck, or the magnitude or direction of the torque tending to turn the plane.

Consider a barricade consisting of vertical elements operating between longitudinal elements which are in turn attached to the arresting engine at either side of the deck. Assume that ten vertical elements engage the wings of the plane. Let the tension in the purchase cable be T. Regardless of the design of the barricade, the smallest possible tension in the most stressed vertical element would be 0.20 T. This will be the case only when the forces in all vertical elements are equal, and when they are all parallel. If under the worst distribution possible only one of the ten elements is operative, the tension in this element would have a maximum value of 2.0 T. Thus there is a range of but ten to one between possible extremes. One can scarcely hope to attain in practice the minimum extreme 0.20 T; the value 0.30 T would be a more practical one for which to strive. At the other extreme, it is easy to design a barricade for which the maximum tension in a vertical element is 1.0 T. This would be the tension if there were but two vertical elements operative, provided the forces in these elements were equal and parallel. Thus the practical range within which improvements are possible is reduced to approximately three to one. Although inspection of the tabular summaries on pages 88 and 138 shows that the torque exerted on the plane does depend appreciably upon the design of the barricade, the torque provided by nearly all configurations is so small that the effect is probably of little significance.

5. Although for any off-center landing it might be desirable that the barricade exert on the plane a component of force toward the center line of the deck and a torque which turns the plane toward the center line, it is the opinion of this group that neither of these characteristics is of great importance in the design. Almost any design will provide a component of force toward the center line for any off-center landing. Inspection of the tabular summaries on pages 88 and 138 shows that only one of the many configurations studied failed to provide such a force. That one was Barricade No. 1, doubly reeved, a design which one would never consider seriously anyway. Further inspection of the tabular summary on page 88 shows that of all the barricades for straight-wing planes studied, No. 10 provided much the most unfavorable torque. The design of this barricade was essentially the same as the barricade now in use for stopping straight-wing planes. The group is aware of no major defect in the operation of this barricade which could be attributed to a highly unfavorable torque. The group is therefore inclined to believe that the magnitude or the direction of the torque exerted on the plane is of little significance. This opinion must be tempered by the following fact. Whereas Barricade No. 10 provides a relatively large unfavorable torque when engaging a plane with straight, thin wings, it would exert a torque at least less unfavorable on a conventional straight-wing plane the wings of which are

actually not only swept back slightly but are also thicker near the fuselage than near the tip. In engaging a conventional straight-wing plane, Barricade No. 10 might well provide a much smaller torque, perhaps more nearly equal to that shown in the table on page 88 for Barricade No. 11 engaging a plane with truly straight, thin wings.

6. It is the opinion of this group that slippage of barricade elements along the leading edges of the wings contributes materially, and usually unfavorably, to the behavior of the barricade. Slippage is almost certainly responsible to a considerable extent for the tearing of both the barricade element and the wing. Tearing induced by slippage probably occurs only when the slipping elements are under large tension. Slippage of lightly stressed elements is probably not objectionable. The principal way to minimize slippage is to utilize a barricade design for which the elements pull in a direction more or less perpendicular to the leading edge of the wing.

7. In order that a barricade shall operate reliably it is essential to avoid entanglement of the barricade elements with the tail fin of the plane. It is of course conceivable that such interference might aid materially in stopping the plane, but one could not rely upon it. Since unpredictable entanglements would often interfere seriously with the normal behavior of the barricade, it is highly desirable to avoid them as completely as possible. In general it appears that in order to minimize entanglement it will be necessary to keep the vertical elements sufficiently short and to utilize a design in which there is no tendency of the longitudinal elements to move laterally across the tail fin as the plane proceeds on its runout. Tendency of the longitudinal elements to move across the tail fin can be eliminated in either of two ways, by using a design in which effectively a single pair of longitudinal elements is attached to the vertical elements in such a manner that they remain near the wing tips at all times (as in Barricade No. 9, page 34), or by utilizing a design (similar to Barricade No. 10, page 43) in which any one of a series of multiple longitudinal elements is attached to two vertical elements one of which is on either side of the plane. The use of multiple longitudinal elements (as in Barricade No. 17, page 72) in which but a single vertical element is attached to each longitudinal element will always increase the possibility of entanglement.

8. It is of considerable importance that a barricade design should lead to a favorable distribution of forces upon engaging not only a plane in a normal landing but also a plane of which the fuselage is not parallel to the center line of the deck. One therefore desires that the force distribution in a barricade be as nearly independent as possible of the angle at which the

fuselage of the engaging plane is oriented with respect to the center line of the deck. Fulfillment of this desire may or may not result in a favorable torque but, as stated previously, the torque is probably of secondary significance. In principle a considerable degree of independence can be attained in either of two ways. Two or more vertical elements can be connected to a pair of longitudinal elements in such a manner that all pull from a common point which is essentially in line with the fuselage. This method eliminates to a large extent the effective use of multiple pairs of longitudinal elements. It also makes it difficult to avoid entanglement. A second possible method is to employ multiple pairs of longitudinal elements and attach with rings to each pair two vertical elements (as in Barricade No. 10, page 43), one vertical element operating on either side of the fuselage. In order to equalize forces in the vertical elements during a landing in which the fuselage is not parallel to the center line, it is necessary that the length of that part of a given longitudinal element between the purchase cable and the first vertical element attached to it become greater on one side of the plane and less on the other side. A design such as No. 10, page 43, is thus partially self compensating. It is fortunate that this design also minimizes the possibility of entanglement with the tail fin.

9. General consideration of the problem of stopping planes having sweptback wings has convinced the group that in stopping such planes the barricade elements must be constructed to sustain considerably larger forces than those encountered in stopping conventional planes. Furthermore, if the forces in these elements are to pull in directions approximately perpendicular to the leading edges of the wings, the forces which must be sustained will become larger as the angle of sweepback increases.

10. It would be advisable if possible to adopt a single barricade which would stop satisfactorily planes having any degree of sweepback from near 0 to 60°. Barricades No. 10 (pages 39 and 90) and No. 11 (page 53) offer the greatest possibility of any of the designs studied. Ties between certain of the vertical elements might be necessary to provide satisfactory operation upon engaging planes with sweptback wings, but these ties would in no way affect the operation upon engaging planes with straight wings. Although Barricade No. 23 (page 129) is in some respects superior to No. 10 and No. 11 for stopping planes with sweptback wings, it would place an undesirably large stress near the tip of the wing in stopping a plane with straight wings.

[illegible]

12. This group is not able to suggest an ent[illegible] rel[illegible] satisfactory barricade for stopping planes with swept[illegible]ings. A design resembling No. 10, modified perhaps [illegible] to the lengths of the vertical elements and the [illegible]ion of flexible longitudinal ties between certain [illegible] the vertical elements, might accomplish the job. [illegible] It would be relatively free from entanglement and rel[illegible]ively satisfactory for skew landings. Rather high [illegible]orces

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speed photograph...
showing the dynamic behavior of the barricade ...
engaging a test plane. This will require the use of
a full scale prototype. The group feels that knowledge
of static characteristics is very much worthwhile, even
though dynamic effects may have a pronounced influence
upon actual behavior. Motion pictures of barricade

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ıas seen are not as ea
.ve as might be hoped.
nd the behavior is not
ngle. It would be we
still slower motion an
. This group believes
directly in front of t
the plane would be mor
from the side. Photo
n front of or directly
arly valuable in studyi
he leading edge of the
ble to take such photog
and operator can be pro
nd taking the pictures
by allowing the camera
nd and use a periscope
ming plane. It would
s pictures from direct
it would be far more
ises whether these woul
tive than those taken
considerably greater

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